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THEORY AND PRACTICE OF GLASS-METAL SEALS

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Introduction

The term "glass-metal seal" could be applied to various combinations in which glass is cemented to metal or metal is cemented to glass through the intermediary of a third substance (e.g., waxes, plastics, etc.), or to combinations in which the surface of the glass is metallized by application of paste, molten metal, electrodeposit, or any other means which permits the use of solder to effect adherence; but in its strictest sense the term is applicable only to those cases in which a seal is made by heating an inorganic glass to a point of sufficiently low surface tension to permit intimate contact with a metal suface, this intimate contact to be retained, at least partially, when the glass and metal have cooled to room temperature. Such a glass-metal seal may be used merely for support, in which case mechanical strength alone is of importance, or it may be used as part of a closed container which is either evacuated or contains gases at atmospheric or greater pressure. In this latter case the seal must be of such a nature that leakage of gas or air along the junction of the glass and metal or through the metal itself does not occur. The use of such "vacuum-tight" seals makes possible the huge lamp and vacuum tube industries—a field which includes all electronic devices, such as incandescent and fluorescent lamps, radio tubes, power tubes for radio transmission, photoelectric tubes, cathode ray tubes, X-ray tubes, mercury switches, and numerous others.

In the lamp and tube industries the problem of making glass-metal seals simplifies essentially to meeting two requirements. The metal must not crack the glass (must not produce deformation which causes the tensile strength of the glass to be exceeded) at room temperature or the temperature at which the lamp or tube is operated. In addition, the seal must not be gassy and the metal must not be porous or in any other way permit passage of gas or air. This second requirement must be met even though the metal does not crack the glass.

Types of Glass-Metal Seals

Classification Based on Function. The primary purpose of glass-metal seals in vacuum tubes, lamps, and other electronic devices is to complete electrical circuits between elements within the envelope and external terminals or connectors of various sorts. This is shown in Fig. 1, where the wires in the stem complete an electrical circuit between the cathode and pins in the base. In many cases the sealed-in-wires are merely supports for elements in the tube, as demonstrated by the center wire in Fig. 2 and two of the wires in Fig. 6d. Frequently the lead wire or lead (pronounced *leed*), so-called from its usual function of "leading in" or permitting passage through the glass, carries current and at the same time supports a tube element. In Fig. 2 the leads in the stem-press in the lower part of the tube carry current and support the cathode, while the lead sealed through the top of the bulb not only completes the anode circuit but is the sole support for the anode. In some cases, particularly in connection with large water-cooled and air-cooled tubes (Fig. 3) the glass-metal seal is made to one of the tube elements, generally the anode, which thus becomes part of the envelope of the tube. Still another type of glass-metal seal is one in which a glass window or screen is sealed to a metal container. Fig. 4 shows a small cathode-ray tube with a glass disc (the fluorescent screen) sealed to a metal shell. In summary, glass-metal seals may be classified into five categories as far as the purpose of the seal is concerned, and these are listed as Classification I in Table 1. All other uses are capable of classification in one or more of these categories.

Classification Based on Geometry. The geometry of seals is one of great diversity. Numerous shapes and sizes are commonly used, depending upon many factors. Among the points which must be considered in making a decision are: voltage and current to be carried through the seal, temperature of operation of the tube, size of

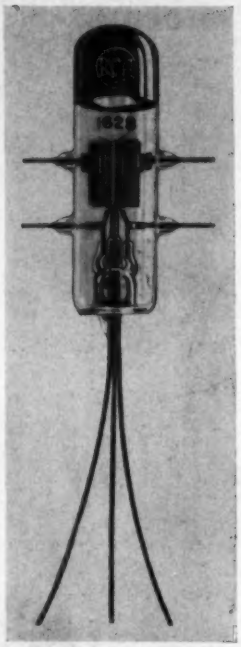


Fig. 1. Electron tube showing glass-metal seals serving dual function of current conduction and supports for tube elements.

the tube, electrolysis in the glass between leads, rigidity of tube elements desired, electrical characteristics of the tube (inter-lead capacitance, for instance), mechanical stresses applied to the seal, skill and machinery available, annealing facilities, and cost of tube. Nevertheless the types of seals fall into definite patterns; these are summarized as Classification II in Table 1.

Discussion of each of the types in this classification is essential to a complete background for treatment of the physics, chemistry, and mechanics of seals which is to follow. The examples cited are merely typical and no attempt is made to describe all types and modifications of seals and tubes. It seems safe to say, however, that all basic designs are included here.

The terms "internal seal" and "external seal" are employed to designate seals in which the metal is enclosed in or surrounded by glass in the former case (Fig. 5.1, 5.2, 5.3) and the glass surrounded by metal in the latter case (Fig. 5.4). An internal seal is generally a rod or wire seal, but there are occasions when it is desirable to lead a ribbon or metal tube through a glass wall. External seals consist in nearly every case of a thin-walled ring or tubular section, flanged or otherwise, which surrounds a solid or essentially solid disc or button, although in a few instances the shape of the glass may be square, rectangular, or otherwise.

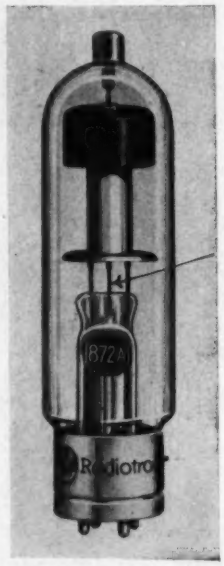


Fig. 2. Half-wave rectifier tube with one glass-metal seal serving only as support.

We further differentiate between internal and external seals of the type described above and "inside tubular" and "outside tubular" seals. The differences are clear. An internal seal in the case of a metallic tube is one in which the wall thickness of the tube is small in relation to the glass thickness around the tube, while the inside tubular seal is one in which the metal and glass thicknesses are more nearly of the same magnitude. Thus, Fig. 5.3 shows an internal seal employing a tubular lead; Fig. 5.6b and 5.7a are examples of inside tubular seals. The same differentiation exists between an external seal (Fig. 5.4) and an outside tubular seal (Fig. 5.6a) and 5.7b). A secondary characteristic is the fact that in general the tubular seals represent an overlapping or telescoping, in which

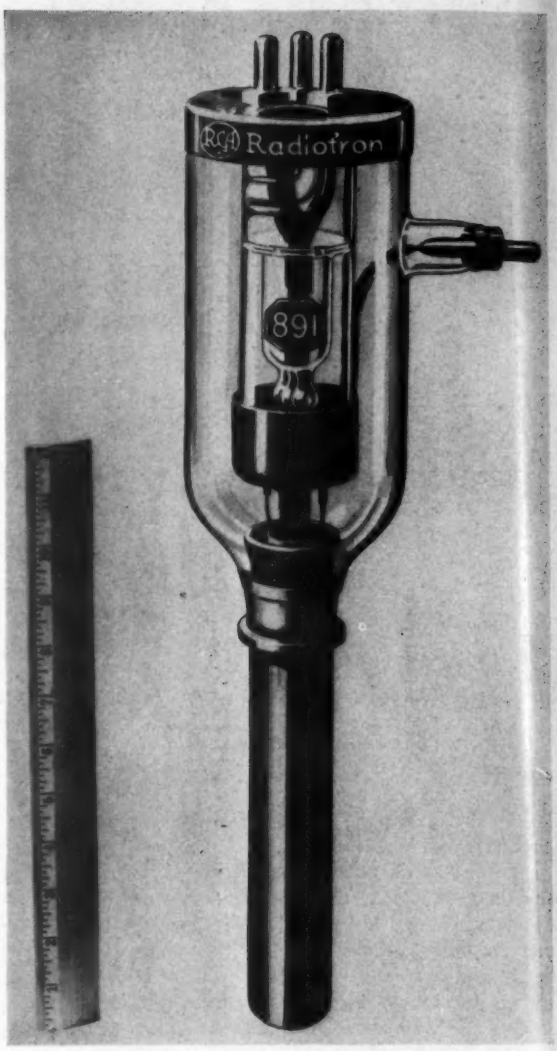


Fig. 3. Transmitting tube, with glass-metal seal made to water-cooled anode.

the actual length of seal constitutes only part of the total length of glass or metal or both. The long copper anode of Fig. 3, with a glass-metal seal at the junction of glass and metal, as well as the cup seal of the terminal which extends to the right, are typical examples of tubular seals.

A. Internal Seals

Conventional internal seals, with round metal wires or rods passing through or embedded in glass, are the most common type of glass-metal seal. Incandescent light bulbs, radio receiving tubes, many special-purpose and power tubes, cathode ray tubes—these and others employ internal seals. Fig. 5.1 shows cross-sections of this type of seal, and the photographs and drawings of Figs. 6, 7, and 8 illustrate some of the various designs that are possible.

Ribbon seals of the kind shown in Fig. 5.2 are not widely used. There are occasions, however, when this design is advantageous. The difficulties of making it successfully on a production basis have probably been the greatest deterrent against wider application.

Very often it is highly desirable to employ a metal

Fig. 4. Metal cathode-ray tube with glass window as fluorescent screen.

tube instead of a solid rod or wire to make connection with the interior of an enclosure. Fig. 5.3 is illustrative of this type of seal. The outside diameter is generally small (rarely over 0.150 in.). If the wall is thin (usually a ratio of not less than 15:1 between outside diameter and wall thickness, with maximum wall thickness of 0.010 in.) there are no restrictions on the choice of metal, other factors being favorable, but if the wall thickness is too great then the tube must be made of metal whose thermal expansion characteristics agree reasonably well with those of the glass chosen.

Internal tube seals are perhaps not used as widely as they should. Since any cross-sectional area of a wire or rod can be duplicated in a tubular structure advantage should be taken of the freedom of design permitted by this fact. The tubular structure of equivalent cross-sectional area generally provides greater current-carrying capacity and greater mechanical strength. A wire or rod with a tubular jacket may be used where size limitations prevail.

B. External Seals

An external seal is one in which a band of metal adheres to the edge of a glass insert. A cross-section is shown by Fig. 5.4. The glass insert may be a round button or disc or it may be square, rectangular, or other shape, although it is well to bear in mind that the non-symmetrical stress distribution in all cases except the round shape makes the maintenance of a vacuum or pressure seal extremely difficult.

The outside ring or band of Fig. 5.13 and of Fig. 11b is a widely used external seal. Fig. 11c shows the method by which the seal is made part of the metal envelope of a radio receiving tube. The entire unit shown by Fig. 11b is a combination seal and is listed under that heading.

C. Tubular Seals

Tubular seals are of two types: (a) the "thin-edge" or "Housekeeper" seal (Fig. 5.6a, b, c, and Fig. 3) and the "normal-edge" or "Kovar" seal (Fig. 5.7a, b, c).

The thin-edge tubular seal is employed when it is necessary to choose a metal which does not match the glass in thermal expansion. In the case of large transmitting tubes the plate dissipation is much too high for conventional tube design. The plate or anode therefore must become part of the tube envelope so that forced air or water cooling can be used on this element. Because of its excellent thermal conductivity, low yield point, machinability, and good adherence to glass copper is invariably chosen. Since copper does not even remotely approach any good electrical glass in thermal expansion,

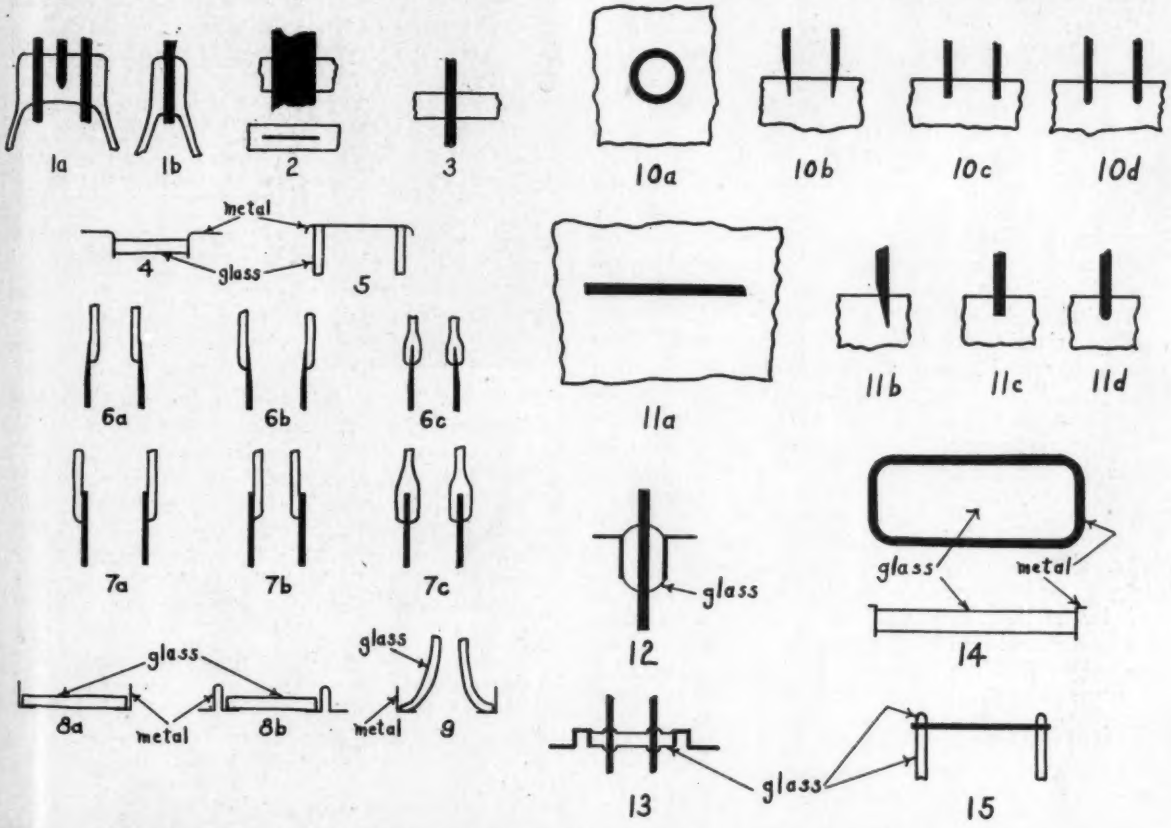
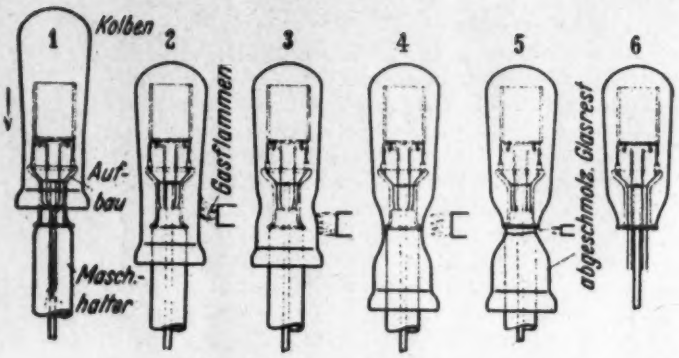
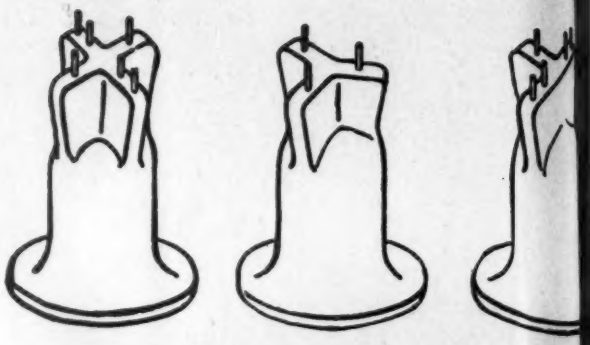


Fig. 5 Geometrical representations of basic types of glass-metal seals.





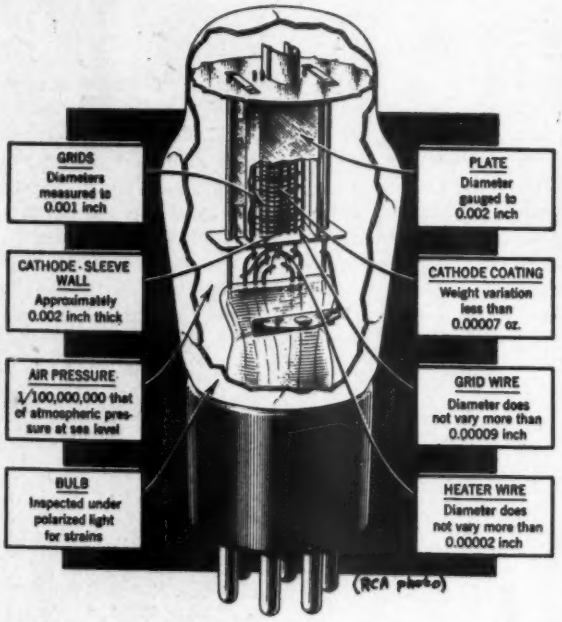


Fig. 6 (a, upper left) Steps in sealing stem into glass bulb (from *Espe and Knoll*); (b, upper right) three types of stem-presses; (c, lower) location of stem in radio tube; (d) typical stem-press with both conducting and support seals; (e) side view of stem press.

it is necessary to employ the thin-edge seal in order that the copper can expand and contract with the glass without damage to the seal.

In some instances, such as certain terminals (side terminal of Fig. 3), copper is chosen because of its high electrical conductivity.

The normal-edge tubular seal employs a metal whose thermal expansion or elongation closely matches that of the glass. Kovar, an alloy of iron, nickel, and cobalt, is the only metal which has found extensive application in the United States. Nickel-iron alloys have been used abroad with some success[1].

D. Edge Seals

An edge seal, as shown in cross-section by Fig. 5.10a, b, c, is one in which the edge of the metal is embedded in glass. It bears some resemblance to an inside-outside tubular seal (Fig. 5.6c and 5.7c) in that it may be thin-edge or normal-edge but the geometry and applications generally differ. The choice of thin-edge or normal-edge is governed by the same factors as in the case of tubular seals.

E. Butt Seals

The simplest type of butt seal is shown by Fig. 5.5, where a metal disc is sealed to the end of a length of glass tubing. Such a seal does not find much practical application. Unless the metal is soft and extremely thin (not much over 0.005 in.) or unless the expansion curves of glass and metal are a good match failure of the seal is very likely to occur. The seal shown by Fig. 5.15, however, is serviceable for many applications with disc thickness as great as 0.030 in. for a diameter of 1 in. in the case of copper. Seals similar to this may be made with thicker metal in the case of Kovar and a suitable glass.

Variations in design of butt seals are common. Fig. 5.9 shows a seal with tubing to a ring with right-angle cross-section. Fig. 10a is a phototube with chrome iron and caps, and Fig. 10b is a Kovar-glass assembly. In all three of these types the metals and glasses match well in expansion.

F. Window Seal

A window seal is one in which a glass window is sealed

[1]Bell, J. Davies, J. W., and Gossling, B. S., *J. Inst. Elec. Eng., 83*, 176-207, (1938).

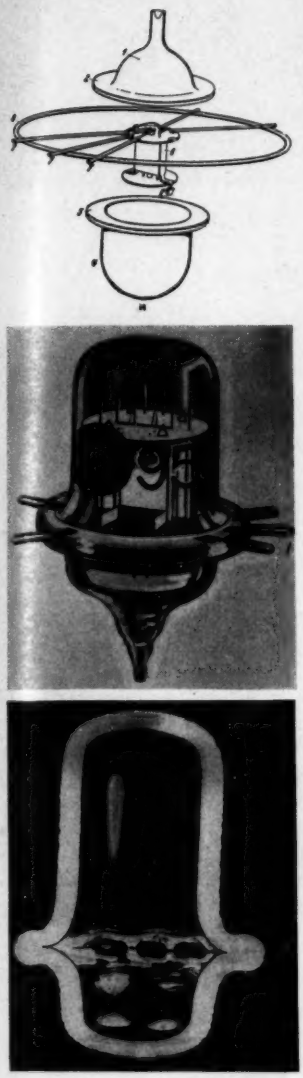


Fig. 7 (a) Method of sealing-in the leads of an "acorn" tube; (b) the completed tube; (c) section through the middle of "acorn" seal without tube mount.

across the open end of a metal container, as shown by Fig. 5.8a and 5.8b. A practical application is illustrated in Fig. 4.

G. Combination Seals

The various types of seals described above are frequently used in combination in the same application. The term "combination seal," however, is reserved for those examples where the use of two or more types together constitute a unit which is used or sold as such. Thus, Fig. 5.12 shows the cross-section of an eyelet seal and Fig. 11a illustrates the method of application by soldering or welding. Fig. 5.13 and Fig. 11b describe the very useful button stem which has made possible large-scale production of metal radio receiving tubes. In both of these instances the units consist of internal and external seals involving a single glass body.

Classification Based on Type of Glass Used. In addition to classifications of glass-metal seals based on function and on geometry a classification based on the type of glass used is very desirable in connection with design and application. For this purpose all glasses are divided into two groups: "soft" glasses and "hard" glasses.

Hard and soft glasses have been defined in various ways. Originally the designations referred merely to the temperature ranges in which the glasses, in the form of tubing, bulbs, and cane, were worked by the glassworker. These temperature ranges are roughly from 800° to 1000° C. for soft glasses and 1000° to 1300° C. for hard glasses. In broad terms of composition the soft glasses are soda-potash-lead glasses and soda-potash-lime glasses with silica contents varying from about 57% to 72%, while the hard glasses are generally borosilicates with silica contents of 72% upward. For purposes of discussing glass-metal seals neither of the above definitions is entirely satisfactory. Therefore, hard and soft glasses will be defined on the basis of thermal expansion coefficients for the temperature range 0-300° C. This is a more rational method of definition since the choice of

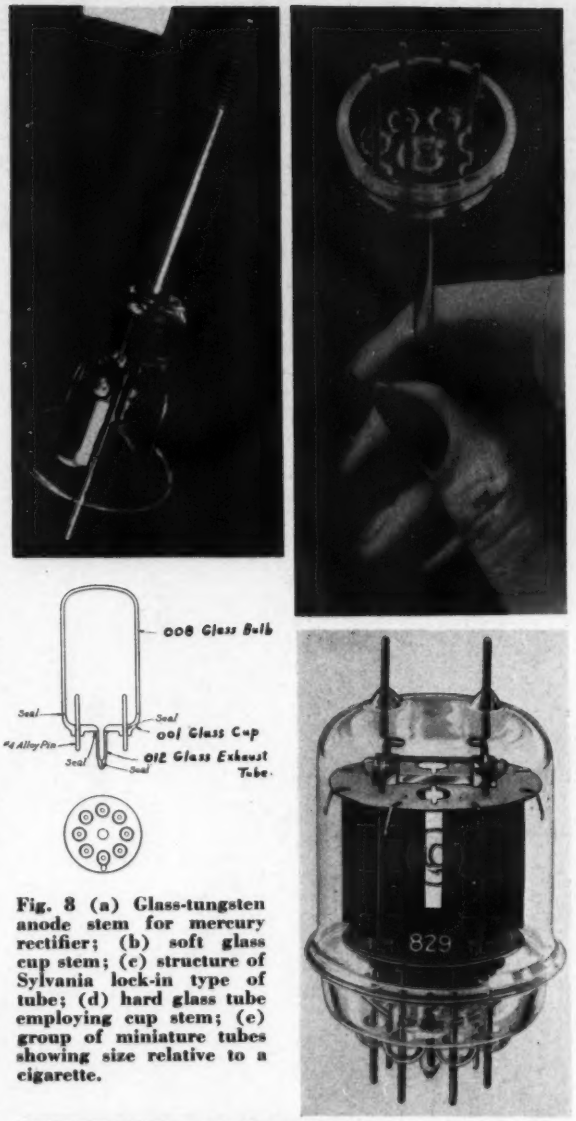


Fig. 8 (a) Glass-tungsten anode stem for mercury rectifier; (b) soft glass cup stem; (c) structure of Sylvania lock-in type of tube; (d) hard glass tube employing cup stem; (e) group of miniature tubes showing size relative to a cigarette.

a glass for a seal is dependent almost entirely upon the expansion and contraction characteristics of the metal to be used. Consequently, hard glasses are defined as those which have expansion coefficients below 50×10^{-7} per degree C., while soft glasses are those which have expansion coefficients above 50×10^{-7} per degree C., the temperature range in both instances being 0-300° C.

Reference to Classification III of Table 1 discloses

TABLE I

CLASSIFICATIONS OF GLASS-METAL SEALS

I. FUNCTION
- A. Completion of electrical circuits
- B. Support for tube parts
- C. Completion of circuits and support for tube parts
- D. Service as tube element
- E. Window or screen as part of tube envelope

II. GEOMETRY
- A. Internal seal
  - a. Wire (Fig. 5.1)
  - b. Ribbon (Fig. 5.2)
  - c. Tube (Fig. 5.3)
- B. External seal
  - a. Metal around edge of disc or round button (Fig. 5.4)
  - b. Metal around edge of square, rectangular, etc., button (Fig. 5.14)
- C. Tubular seal
  - a. Thin-edge metal
    - 1. Inside (Fig. 5.6b)
    - 2. Outside (Fig. 5.6a)
    - 3. Inside-outside (Fig. 5.6c)
  - b. Normal-edge metal
    - 1. Inside (Fig. 5.7a)
    - 2. Outside (Fig. 5.7b)
    - 3. Inside-outside (Fig. 5.7c)
- D. Edge seal
  - a. Tubular (Fig. 5.10a)
    - 1. Thin-edge (Fig. 5.10b)
    - 2. Normal-edge (Fig. 5.10c)
    - 3. Rounded-edge (Fig. 5.10d)
  - b. Non-tubular (Fig. 5.11a)
    - 1. Thin-edge (Fig. 5.11b)
    - 2. Normal-elge (Fig. 5.11c)
    - 3. Rounded-edge (Fig. 5.11d)
- E. Butt seal (Fig. 5.5) (Fig. 5.15)
- F. Window seal (Fig. 5.8a, b)
- G. Combination seals
  - a. Eyelet (Fig. 5.12)
  - b. Button stem (Fig. 5.13)

III. TYPE OF GLASS
- A. Soft glasses
  - 1. Thermal expansion coefficients greater than 50×10^{-7} per deg. C. (0° to 300° C.)
  - 2. Used for all types of seals under Classification II
  - 3. Generally used with: Dumet, 28% chrome iron (Sealmet 1), Sylvania No. 4, Driver-Harris No. 14, Carpenter "426", SAE 1010, copper
- B. Hard glasses
  - 1. Thermal expansion coefficients not greater than 50×10^{-7} per deg. C. (0° to 300° C.)
  - 2. Used generally for internal, tubular, edge, and butt seals; other types occasionally
  - 3. Generally used with: tungsten, molybdenum, Kovar, copper

that soft glasses may be used for all types of seals listed under Classification II and already described. Hard glasses, on the other hand, find their greatest application in internal and tubular seals, although edge and butt seals with these glasses have come into greater prominence. Theoretically of course hard glasses can be used for all types of seals listed under Classification II. Even platinum in the form of thin-walled tubes has been sealed through Pyrex glass to form a vacuum seal[2] despite the disparity in expansion coefficients.

Copper has been used extensively in the form of a thin-edge tubular seal with both soft and hard glasses.
to metals are extremely important and require complete

Properties of Glasses

Certain properties of glasses to be used for sealing

[2]Wichers, E. and Saylor, C. P., *Rev. Sci. Instru., 10,* 245-250 (1939).
[3]Littleton, J. T., *Ind. Eng. Chem., 25,* 748 (1933).
[4]Lillie, H. R., *J. Amer. Ceram. Soc., 14,* 502 (1931); 16, 619, 625 (1933).
[5]Littleton, J. T. and Roberts, E. H., *J. Optical Soc. Am., 4,* 224-29 (1920).
[6]Twyman, F., *J. Soc. Glass Tech., 1,* 61-73 (1917).
[7]Adams, L. H. and Williamson, E. D., *J. Franklin Inst., 190,* 597-631; 835-70 (1920).

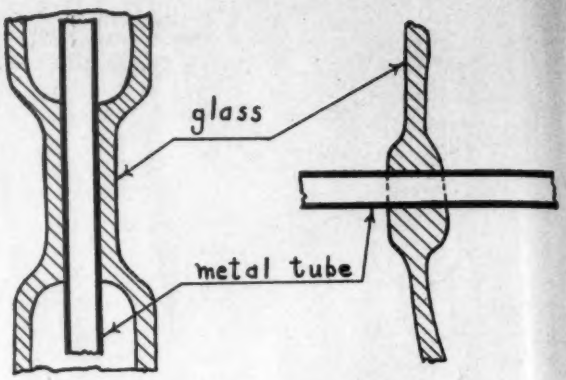


Fig. 9. Two types of thin-wall tube seals.

definition and explanation. These properties may be classified as *thermo-viscous, physical, electrical,* and *photo-elastic* and are so discussed below.

Thermo-viscous Properties. If a plot of viscosity versus temperature is drawn it is possible to define all of the thermo-viscous properties in terms of definite viscosities. In Fig. 12 the smooth curve is a hypothetical relationship between viscosity in poises and temperature. Each particular glass composition has its own curve but the reference points and ranges defined by means of the curve vary only in temperature from glass to glass.

When a glass is heated from room temperature there is very slow decrease in viscosity. As heating progresses the rate of decrease begins to accelerate when a certain temperature range is reached. This range, in which many properties of glasses show abrupt changes, has been called the "transformation point," although the validity of this conception at equilibrium conditions is doubtful[3]. The viscosity in this temperature range is between 10^{14} and 10^{15} poises. By making an arbitrary choice of a point on the curve (Fig. 12) in the vicinity of the transformation point it is possible to define the *strain point* as follows: *The strain point of a glass is the temperature at which the viscosity has a value of* $10^{14.6}$ *poises*[4]. Other meanings attach to the strain point. It is the lower end of the annealing range. It is the temperature below which there is practically no viscous yield. It is the temperature of intersection of the temperature axis by the temperature-log curve[5]. At the strain point glass is said to anneal in 16 hours. At the same point 90% of all strains in a sample of glass ¼ in. thick are said to be removed in 4 hours. The strain point is the highest temperature from which strain-free glass can be cooled quickly without introducing permanent strain. This last conception is the one of greatest value in connection with glass-metal seals.

Returning to Fig. 12, as the temperature increases another point, the *annealing point,* is reached. *The annealing point is the temperature at which a glass has a viscosity of* $10^{13.4}$ *poises.* The annealing point is the upper limit of the annealing range, and is the temperature at which 90% of the strain in a sample ¼ in. thick is removed in 15 minutes.

The mobility of glass is an exponential function of temperature[6, 7]. Twyman stated that the time of annealing was halved for each rise of 8° C.; Adams and Williamson found 8° to 11° according to the glass; while

(*Continued on page* 408)

ON THE FLUORESCENCE AND PHOTOCHEMISTRY OF GLASS

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Using Bohr's model as a basis it becomes obvious why a large number of materials show the phenomenon of fluorescence. One of the outer electrons is raised into a higher energy level causing the atom to assume a state of higher energy. The energy of the "excited" state is provided by the absorption of a light quantum. Because of the higher energy content such an excited atom is unstable with respect to its ground state and tends to return to its normal conditions. In diluted gases or vapors the most probable way to do so is the emission of a light quantum having the same frequency as the absorbed light: resonantial fluorescence. If the atom has a chance to convert some of its energy into another form, such as kinetic energy, the emitted light quantum will be smaller than the one which had been absorbed. The fluorescence in this case consists of light which has a longer wave length than the one which caused the excitation. (Stokes Law)

For most purposes this simple picture will prove adequate for explaining the fluorescence of many materials; such as gases, liquids and solids. No assumptions have to be made as to the mechanism for converting the light energy or part of it into kinetic energy. But it seems obvious that resonantial fluorescence can be expected only if the lifetime of the excited atom is short as compared with the time interval between two atomic collisions. It is also obvious that the probability of converting the energy of the absorbed light into heat or chemical energy increases with increasing probability of atomic collisions. There are only few substances which fluoresce above 300°C. If we want to make fluorescence more probable, we must see that the absorption center is "energetically isolated" so that it does not have much chance to dissipate its energy by transferring it to its nearest neighbors.

Fluorescence is usually defined as re-emission of irradiated light and in most cases the emitted light has a longer wave length than the light which causes the fluorescence. Fluorescence ceases practically instantaneously with the excitation. Phosphorescence is a process related to fluorescence. The light emission continues for some time and, to be more exact, phosphorescence requires the cooperation of thermal motion. By cooling a phosphorescent material to low temperature, phosphorescence can be frozen in and the absorbed energy can thus be stored until the thermal agitation of the molecules causes the liberation of light quanta on heating.

Glasses show similar phenomena as crystalline materials but the lack of symmetry prevents sharp fluorescence bands. At elevated temperature or even at room temperature crystals too may have diffuse fluorescence bands. As a rule, these bands become narrower and sharper as the crystal is cooled to the temperature of liquid air. In other words, the broadening of fluorescence bands in crystals is due to thermal motion. In glasses the assymetry and the difference of the constituting units adds to the broadness of emission bands, and this factor remains even at absolute zero. Fluorescent glasses, like crystals, can emit radiation in the u. v. visible and infrared region. Resonantial fluorescence cannot occur in liquids or solids. No matter how weak the forces are which are holding the fluorescent centers in the structure of the solid, the latter are always exposed to the electric fields of the neighboring molecules. In order to produce fluorescence in glasses, we have to bring in absorbing units which can be energetically isolated. Let us first derive a classification for fluorescent glasses and then show how, in the different cases, energetic isolation is accomplished. Instead of classifying fluorescence according to the chemical nature of the centers responsible for the phenomenon, we prefer to base our classification on the participation of the glass structure. From this point of view the first group comprises those glasses which contain fluorescent centers foreign to the glass structure. Vitreous enamels have been developed by Sauvagé which contain zinc sulfide or similar high melting crystalline phosphors in the place of opacifiers. From a scientific point of view this group of phosphorescent or fluorescent glasses is of no particular interest. They are simply a combination of glasses with high melting crystalline materials. Their properties are determined by the crystalline materials only. They belong in the same group as fluorescent paints containing a crystalline fluorescent material and an organic laquer as a vehicle. Interesting to the glass technologist is the possibility that fluorescent crystals can be precipitated from proper glass compositions. For example glasses containing a large amount of zinc oxide are likely to devitrify and precipate zinc orthosilicate. We found that zinc orthosilicate, which occurs in nature only in one modification (Willemite) can be obtained from glasses in two different modifications. At 850°C or higher, the stable modification crystallizes out but at lower temperature, around 700°C an unstable crystalline modification probably having cristobalite structure is formed first. When activated with small amounts of manganese both modifications fluoresce and phosphoresce. The stable one green; the unstable one yellow. Another opal glass which contains a crystalline material can be developed on the basis of zinc vanadate. Like the pure crystal, such a glass shows a strong yellow fluorescence but no afterglow. In both cases we have to deal with fluorescent crystals.

There are, however, also some glasses which show fluorescence due to energetic isolation of molecules or atoms. One of the most effective ways to produce this state is based on introducing molecules of organic compounds into inorganic glasses. The instability of organic molecules at high temperature imposes a serious limitation. Nevertheless, a number of brilliantly fluorescing glasses have been developed by introducing terephtalic

*Lecture given in Physics Seminar at the Naval Research Laboratory, Washington, D. C., June 12, 1946.

acid and similar compounds into low-melting boric acid or borate glasses. The abrupt change from an organic material to a grouping of ions prevents easy dissipation of energy and favors fluorescence. With increasing polarity of the solvent, fluorescence of dissolved molecules decreases. Based on this interaction between solvent and solute the fluorescence of certain organic dyes has been used to estimate the unknown polarity of solvents. Dimethylnaphtheurhodine, for instance, shows bluish-green fluorescence in non-polar liquids, like hexane; yellow fluorescence in chloroform, and reddish fluorescence in alcohols. The same phenomenon has been observed in glasses. If we introduce fluorescing centers like the UO_2^{++} group into borate glasses, we find that their emission bands are shifted to longer wave lengths if the alkali content is increased. As compared with water, glasses provide a solvent for many ions which favors fluorescence. With the exception of some rare earths ions and the uranyl group, there are no simple ions which show fluoresecence in water. In glasses, however, many ions; such as, V^{5+}, Mn^{2+}, Cu^{+}, Tl^{+}, and Pb^{2+}, exhibit bright fluorescence. The presence of alkali modifies the fluorescence and as a rule potassium exerts the weakest influence and lithium the strongest. Sodium assumes an intermediate position. With decreasing ionic size, or increasing electric field, the emission bands become weaker, broader and are shifted to longer wave lengths.

The phenomenon of quenching, which is so characteristic for the fluorescence of crystals and solutions occurs also in glasses. Changing the anion from O^{2-} to the less polarizable F^{-}, increases fluorescence, but introduction of the more polarizable bromine or iodine makes fluorescence impossible. The effect which iron has on fluorescence is not yet fully understood. Like in crystals, traces of iron decrease the fluorescence intensity of glasses.

The effect of increasing the concentration of the fluorescent centers is similar to that in solutions. The concentration of an ion which still allows fluorescence in glasses depends on the position which the glass constituent has in the structure. The same applies to temperature quenching. This can best be illustrated by the fluorescence of manganese glasses. The divalent manganous ion is one of the best known fluorescent centers. It can participate in the network proper where it is surrounded by four oxygens and assumes a role similar to silicon. Under these conditions its fluorescence is green and it is strongly influenced by the concentration. If manganese participates as a network modifier; that is, assuming a role similar to the alkali, it exhibits orange or reddish fluorescence. Glasses with 15% manganous oxide have been made which still possess orange fluorescence. Raising the temperature of such a glass to only 100°C decreases the fluorescence intensity very strongly. In network-forming positions where the ion is much stronger bound and less likely to vibrate, even 200°C does not decrease the fluorescence intensity materially.

Energetically isolated fluorescent centers in glasses may be obtained by distributing metal atoms in the melt and preventing their aggregation. The pink selenium glasses are one example. They contain elemental selenium and exhibit a red fluorescence when irradiated with green light. An original method to produce silver atoms in a glass is based on the reduction of silver ions with hydrogen. It is favorable to carry out the reduction at relatively low temperature (100°C) because, otherwise, the silver atoms aggregate to crystals.

The formation of molecules with a different type of bonding than the surrounding glass is also an efficient means of providing the isolation necessary for fluorescence. Cadmium sulfide might be chosen as an example. Cadmium ions and sulfide ions are colorless. The formation of CdS molecules produces yellow color. Glasses to which cadmium oxide and sulfides have been added during melting are colorless. Reheating, however, brings about cadmium sulfide formation and with it a yellow color and a strong orange fluorescence. The fluorescence is produced by CdS molecules, which are energetically isolated from the rest of the glass. If these molecules are allowed to form crystals by further heat treatment energy dissipation becomes possible within the crystal and the visible fluorescence ceases. Natural crystals of CdS (greenockite) or cadmium sulfide precipitated from an aqueous solution do not show visible fluorescence. If we want to produce the energetic isolation necessary for the fluorescence, we can adsorb cadmium ions at an organic medium and expose these ions to hydrogen sulfide. A filter paper immersed in a diluted solution of cadmium acetate and dried, produces a strong yellow fluorescence when hydrogen sulfide is passed over it and the paper is irradiated with filtered u. v. light.

From a technical point of view the fluorescence of glasses has been used for producing light sources. In some cases, like in uranium glasses or cadmium sulfide glasses, their function is to change the ultraviolet radiation into visible light. In other cases, for example in cerium oxide containing phosphate glasses, their function is to change the short wave u. v. into long wave u. v., so that the both regions can be utilized to produce fluorescence.

From the scientific point of view the fluorescence has been used as a tool for studying the atomic structure of glasses. The fluorescence of an ion like manganese is influenced by its surrounding. The fluorescence spectrum, therefore, tells us something about the surrounding of this ion and how the environment is affected by changes in composition.

Another application is based on the fact that uranium glasses show a very strong fluorescence. The uranium oxides or the sodium uranate, however, do not fluoresce. This has been used to study the temperature where glass formation begins in glass batches and ceramic bodies.

Up to this point we have treated fluorescence as a purely physical phenomenon. When an ion or a molecule absorbs a light quantum one of its electrons is raised into a higher energy level and on its return to the ground state energy is emitted in the form of radiation. The system has undergone no permanent change. We will see, however, that in many cases, the system actually undergoes a change in constitution. If, for instance, a lead glass is exposed to low speed cathode radiation, it shows a green fluorescence. If we increase the speed of the electrons, the glass not only shows fluorescence, but also phosphorescence. This phosphorescence has been called chemiluminescence by early workers in this field because under the bombardment of electrons a chemical change was supposed to take place and the restoration of the original state is responsible for the afterglow. But also in the first case, where only fluorescence has been observed, the glass has actually under-

gone a change because now it emits light on heating. Its "thermoluminescence" is the emission of energy which accompanies the transformation of the changed glass into the original one. No sharp distinction can be made between fluorescence and photochemical phenomena.

Practically all commercial glasses of the window glass or bottle glass type exhibit the phenomenon of solarization. They change their color when exposed to intensive sunlight. Faraday, in 1825, was probably the first to describe the phenomenon. It received a great deal of attention when photography was commercialized. There are several papers on the solarization of window glass, published between 1860 and 1870, because the changes produced by irradiation caused considerable loss of the actinic radiation. Photographers, therefore, had to be careful with the selection of windows for their studios. An explanation for the process of solarization was given by Pelouze in 1867. This French scientist interpreted the purple colors observed in many glasses after exposure to sunlight as the oxidation of the lower oxide of manganese by the higher oxide of iron. Today, where we write such reactions in ionic form instead of using the oxides, a more correct picture is obtained. One can say that the solarization consists of an electron transfer. The divalent manganese ion under the influence of radiation loses an electron and changes into the trivalent manganese. The latter is purple.

There are a great number of these photochemical reactions which can take place in glasses. Photochemical reactions have much in common with electrochemical reactions—both can accomplish chemical changes which cannot be obtained by the application of heat. Thermal energy may produce undesirable side reactions, whereas the absorption of light quanta or the removal or addition of electrons can produce a change in a specific molecule or ion without affecting the surrounding. By photochemical reaction, for instance, it is possible to obtain the purple divalent vanadium ion in glass; which has not yet been produced in glasses by temperature or reducing agents.

The basic laws for photochemical processes are the Grotthus-Draper Law and the Bunsen-Roscoe Law. The first states that only absorbed light can produce chemical changes. Light passing through the system without absorption is inactive. It does not state, however, that the light has to be absorbed by the reactant proper, that means it is possible that any constituent absorbs the energy and transfers it to the reactant. The sensitized photographic plate is a well known example. Some organic dyes which are not bleached in aqueous solutions or when adsorbed at zinc oxide or lead carbonate, are destroyed by light when adsorbed on titanium dioxide. The reason is that the first group of media do not absorb the u. v. light available in daylight, but the titanium dioxide does. From the titanium dioxide the energy in one form or the other is transferred to the organic molecule and causes its destruction. This possibility is important for a complete understanding of solarization phenomena in glasses.

The second law tells us that the amount of absorbed energy is important for the photochemical change but not time and intensity of the radiation taken as separate factors. According to the Bunsen-Roscoe Law, it is possible, for example, to accelerate a solarization process by increasing the intensity of the radiation. Very often, however, two factors have been overlooked when workers in the field of testing materials developed an accelerated test on this basis. The first factor which has to be controlled is the wave length of the light. Solarization is caused by the u. v. portion of the sunlight. If we want to test a material under sunlight, no wave length should be used which is not actually present in sunlight. Some workers, for instance, came to the erroneous conclusion that pure alkali lime glasses, free of iron, manganese or titania, undergo solarization. However, their accelerated test was made with a wave length much shorter than that available in sunlight. They observed the formation of sodium atoms (F-centers) which possess visible absorption under conditions totally different from exposure to sunlight. Another factor which must not be overlooked in an accelerated test is the antagonistic effect which longer wave lengths may exert. In filtered u. v. light, for instance, changes can be observed which do not take place in sunlight, even if the sunlight contains the active wave length. The reason is that besides this active wave length the sunlight contains longer wave lengths which bring about the opposite change. The quenching of phosphors by infrared radiation is well known. The same process takes place in the photographic plate when long wave radiation partly erases the latent image produced by short wave radiation (Herschel Effect). Even if the quantum efficiency of this Herschel Effect is very small, one must consider that the intensity of the long-wave radiation in sunlight is much greater than that of the active u. v. radiation. We may say, therefore, that an accelerated test can be universally employed only if the intensity distribution of the light source is approximately that of the sunlight. It should not contain radiation of shorter wave lengths, but it must contain also the radiation of longer wave lengths because of its possible antagonistic effect.

One photochemical reaction, namely, the reduction of trivalent to divalent vanadium in glass has found some practical application. Soda-lime glasses containing small amounts of cerium oxide (0.5%) and of vanadium oxide (0.5%) are light green because of the presence of V^{3+} ions. Under the influence of sunlight in particular under the influence of the near ultraviolet, the following reaction takes place:

$$V^{3+} + Ce^{3+} \rightarrow V^{2+} + Ce^{4+}$$

Divalent vanadium is formed which imparts a purple color to the glass. This solarization process has been used for producing decorative effects and for measuring the ultraviolet radiation in different places for climatological purposes.

CLYDE WILLIAMS RECEIVES HONORARY DEGREE

Clyde Williams, Director of Battelle Institute, was presented the honorary degree of Doctor of Science at recent convocation ceremonies of the University of Utah of which Dr. William is an alumnus. The degree was presented in recognition of Dr. Williams' wartime and peacetime contributions to American technology.

Dr. A. R. Olpin, President of the University, presented the degree and cited Dr. Williams' accomplishments in research administration and in directing the activities of the War Metallurgy Committee of the National Academy of Sciences and the National Research Council.

PROPOSED SHIPPING CARTON RULES THREATEN GLASS INDUSTRY

No group of railroad shippers is more capable and conscientious with respect to packaging for freight shipments than the manufacturers of glass containers. Cartons must be good enough not only to deliver the glass containers safely to the customer but to be re-used by the customer for reshipping the glass containers packed with his product.

Hence the glass industry, according to B. H. Taylor, Traffic Director of the Glass Container Manufacturers Institute, has more at stake in adequate packaging of glass containers and products contained in glass containers for transportation purposes than have the railroads.

The railroads of the United States, acting in unison through a "Consolidated Classification Committee" to tighten up on packaging standards in a special docket on Rule 41 pertaining to fibre boxes have drawn up a new set of specifications for fibre shipping containers which, if adopted, would cost the glass industry something like $16,000,000 a year while saving the railroads only some minor part of damage claims questionably estimated at $2,000,000.

Although the Committee's proposed revision of Rule 41 is a serious threat to the glass manufacturing industry, glassmen generally feel that it is the intention of the railroads to deal fairly with shippers as evidenced by the public hearings on the proposed rule and to which shippers were invited to attend.

Despite this indication of fair play on the part of the railroads, either in ignorance or contempt of recent improvements in carton design, the Committee drew up rules which would freeze packaging at standards already archaic. Instead of specifying standards of performance, they specified standards of design. In this respect the rules resemble this country's local building construction codes, notoriously responsible for keeping the industry still in a primitive state.

The only reason given by the Committee to justify the proposed rules is that loss and damage to carton packaged freight has since 1941 been unduly excessive, the chief cause being that fiber cartons have been and continue to be used which do not afford sufficient protection to their contents while in the custody of the railroads. No data applying specifically to glass container packaging or discounting wartime conditions was provided.

As pointed out by J. L. Sprowls, Assistant Traffic Manager of the Hazel-Atlas Glass Company, shippers were not told whether the increase has occurred on glass containers or on flat glass, or on other types of glass, or what the percentage of increase on each class has been. No allowance has been made for the fact that traffic tonnage has increased enormously, that the average weight of containers in a car has greatly increased, that cars have received rougher handling, that the quality of corrugated boxes has greatly deteriorated due to paper shortages and that millions and millions of second-hand boxes have been used.

A basic criticism which may be leveled at the railroads is that in revamping Rule 41 no rational justification of the proposed changes has been offered and the action has had the effect of transferring the burden of defense on the shippers.

Placed in this position and with so much at stake, shippers, of course, attended the hearings which have been held. Addressing the Committee at the Chicago meeting on June 26, Mr. Taylor said:

"This is not the way our industry would have preferred to deal with the Consolidated Classification Committee in the matter of an appropriate tariff rule setting up fiber glass containers. The industry has for some months been conducting a two-phase carton performance program. One is by exhaustive tests by a professional testing laboratory to develop standards based on performance which can be translated into a suitable tariff rule. The other is a long-range research program designed to develop improved carton packaging methods. We had hoped there would be sufficient time for us to complete the first phase of this program before any proposal to revise the fiber carton specifications in Rule 41 was released, our thought being that we would be able to make the data developed available to Classification Committees and to the carriers and that it would assist in the determination of a carton packaging rule which would be acceptable to both the carriers and to the industry. I am sure the Classification Committees are fully informed of what I have described as the first phase of our carton performance testing program.

"We were a party to the suggestion that was made to the Classification Committees and the carrier chief traffic officers that a committee representing both purchaser and supplier of transportation be set up to deal with the subject. We renew that suggestion."

Apart from misplacing emphasis on standards of materials and methods instead of on standards of performance, the outstanding features of the proposed rules are the requirement of greater paper weight and of compression testing.

With respect to the requirement of more paper, Mr. Sprowls indicated that the recommendation had not been based on a scientific study of the problem and that the Committee had simply gone back to the types of cases designed thirty-five or forty years ago and added additional paper on the theory that the more paper you have, the more protection you get—a theory which was exploded long ago. By this proposal, said Mr. Sprowls, a bottle holding ⅛ oz. of nail polish must be packed in the same type of case as a bottle holding a pint of syrup; a jar holding a pound of coffee must be packed in the same type case as a jug holding a gallon of vinegar.

Commenting on the recommendations for compression testing, Raymond Wells, Chief Packaging Engineer of Armstrong Cork Company, said that compression tests are a measure of a static load placed upon empty cartons and do not in any way evaluate the protecting value of the carton or interior parts; neither do they indicate what resistance may be offered by the filled carton due to the support given the carton by its contents. Therefore, a

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OBSERVATION OF GOLD PARTICLES IN GLASS WITH THE ELECTRON MICROSCOPE

By G. S. BACHMAN, R. B. FISCHER, and A. E. BADGER

Introduction

Many researches have been made on the colors due to colloidal gold, both in glasses and hydrosols. One of the most striking properties of these colloids is the dependence of color on the size and shape of the gold particles. In glasses containing gold Zsigmondy[1] found particles ranging in size from 4 to 791 millimicrons, with colors changing from pink to red to blue to colorless with increasing particle size. By the use of the X-ray method, Scherrer[2] found gold particles with diameters of only 1.86 millimicrons, and this particle size was checked as 1.6 millimicrons by osmotic pressure measurements. Since the particles in ruby glasses are so minute, they are invisible under the highest magnification available in ordinary microscopes. With the use of the ultramicroscope, however, the colloidal particles appear as points of light on a dark field, where they can be counted.

The electron microscope presents possibilities in this field as it has in so many others. Actual measurement of particle size and determination of particle shape is made possible by the use of this instrument. Unfortunately, since the streams of electrons used in this microscope cannot penetrate films of appreciable thickness, it is not possible to view the gold particles by transmission through the glass. However, the gold particles can be freed from the glass and then viewed.

Some Previous Investigations

The formation of gold particles in glass may be considered to take place in several steps. The gold is originally present in the glass in the trivalent ionic condition, which may impart a faint yellow color to the glass. During the "striking" of the ruby color, which takes place during a controlled heat-treating process, the trivalent gold ions are first reduced to the monovalent condition, with an accompanying loss in the intensity of the yellow color. Next, the monovalent ions are reduced to atomic gold. Lastly, these gold atoms aggregate to form the gold particles which normally impart a characteristic red or "ruby" color to the glass.

Mie[3] explained the color of colloidal gold sols by the simultaneous action of absorption and reflection of the gold particles, which have a sharp absorption maximum in the green and a maximum reflection in the yellow red. Very small particles reflect weakly and absorb strongly, producing ruby solutions. Large particles reflect strongly, the curve of pure absorption becomes lower and flatter, and the solution is blue. Mie then computed theoretical absorption curves for various particle sizes in gold hydrosols, plotting the wave length of light against the percentage absorption. These curves clearly showed that the color of the sol changed from red to blue with increasing particle size.

Lange[4] obtained the absorption curves of gold hydrosols containing particles of measured diameters and found good agreement with Mie's theory. Lange also studied gold ruby glasses, in which case the absorption curves would differ from gold hydrosols due to the differences in the dielectric constants and refractive indices of water and glass. For a commercial gold ruby glass similar to that used in this report, he found that the particles were about 60 millicrons in diameter.

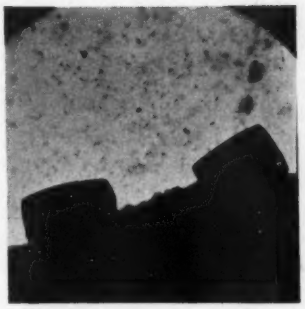

Figure 1. Particles of gold in sapphire-blue glass projecting from edege of minute glass fragment. Edge of particle about 1250 millimicrons (1/20,000 inch). Magnification 10000 x.

Experimental Procedure

The glass used for the following tests was an unstruck ruby glass made by the Glaceries St. Gobain, France[5]. The composition was similar to that of an ordinary soda-lime-silica glass, with the addition of a trace of gold. The glass was nearly colorless in the unstruck condition.

Pieces of this glass were placed in small porcelain crucibles and heated for 4½ hours in a Globar furnace equipped with automatic temperature control. The temperatures used in the treatments were 600°C, 700°C, 800°C, and 900°C, respectively.

The variously-colored pieces of glass obtained in this manner were each broken into two or more pieces. Pieces representing each of the four heat-treatments were ground and polished to one-millimeter thickness for measurements of spectral transmission. The remaining pieces of "struck" glass were placed in platinum crucibles and treated with hydrofluoric acid. The crucibles were placed on a hot plate, and the acid evaporated almost to dryness. Then distilled water was added to the contents of each crucible, and the resulting supernatant liquid decanted off into beakers. The effect of the hydrofluoric acid was to dissolve the glass, setting free the gold particles, which were not attacked by the acid. Thus the final product was a suspension of minute gold particles in a very dilute solution of hydrofluoric acid, the acid being too weak to possess any deleterious effects.

In making test specimens for the electron microscope,[6] a drop of the suspension was placed on a previously-prepared collodion film and evaporated to dryness. The gold particles, as well as any other particles in the suspension such as fluorides and undissolved glass, were thus deposited on the collodion film and ready for viewing in the electron microscope.

Spectral transmission curves were obtained for each of the polished glass specimens by means of a General Electric Recording Photoelectric Spectrophotometer.[7] Thus the color of the glass could be associated with the size of the gold particles in the glass.

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INVENTIONS AND INVENTORS

A Summary of Recently Issued Patents of Interest to the Glass Industry

Feeding and Forming

Patent No. 2,402,234 is an improvement applied to the Hartford-Empire I-S Machine and it was assigned to that company by the inventor, Walter K. Berthold. The I-S Machine, in which the invention is incorporated, is shown in Patent No. 1,911,119 to Ingle.

In this invention, the gob is dropped through the open bottom of a neck-down parison mold onto the tip of a plunger which stops the gob before it reaches the neck ring. The plunger immediately moves up pressing the glass against air pressure which forces the glass downwardly to form the finish in the neck ring. The plunger is then withdrawn and air presses the glass upwardly against a bottom plate. The parison is then ready to be inverted and transferred to the blow mold in the usual way.

The invention may be used to make narrow neck ware, but it is shown in these figures as applied to a machine for making wide mouth ware. Fig. 1 shows a parison mold 21 and an associated neck mold 22 and thimble 23. A charge of glass or gob 25 has just been received on the tip of a plunger 24 which stops the gob before it reaches the finish in the neck ring. A blow head 9 then applies air to the upper surface of the glass and the plunger moves up pressing the charge against the air and forming the finish as shown in Fig. 2. The funnel is next removed in accordance with usual I-S practice and the plunger 24 is withdrawn as in Fig. 3. Then the blow head 9 is again placed on top of the mold, also as in usual I-S operation, and blowing air is admitted around the plunger as shown in Fig. 4. Fig. 5 shows the parison mold open ready for the invert and transfer to the blow mold where the article is blown in the usual way.

Operating mechanism, which may be employed, is shown in a patent application of George E. Rowe which is not yet issued. The advantage of this invention is that slight variations in the weight of the charge will not affect the plunger stroke.

Patent No. 2,402,475 is a device for cooling the suction molds of an Owens machine. It was assigned to Owens-Illinois Glass Company by the inventors, Neil M. Waterbury and Roger C. Tittel. This invention takes air at a low pressure and applies it continuously at a high pressure against the outside only of the mold.

In Fig. 6 the invention is shown as adapted to use with a plural cavity Owens suction mold. The blank mold 15 has two cavities 14. The mold halves are carried by arms 16 mounted to swing about a pivot 17 as is usual in Owens machines. Two yokes 20 are fixed to move with the mold halves. Air is supplied to the yokes 20 through flexible hose 28 and discharged against the outside of the mold through cylindrical nozzles 26. These cylinders may be rotated so as to blow air against the mold through one or more vertical rows of holes. This also provides means for adjusting the angle of the air jets.

Additional blowers 40 are provided to cool the bottom of the mold when in open position. The blowers 40 are mounted on arms 42 (shown in dotted lines) which may be arms such as shown in two patents to La France, Nos. 1,641,497 and 1,739,845. As the discharge openings of these nozzles or blowers are of relatively small total area, a low pressure source of air provides a large number of high velocity jets which are applied to the outside and bottom of the mold thus maintaining a constant desirable temperature to the mold halves.

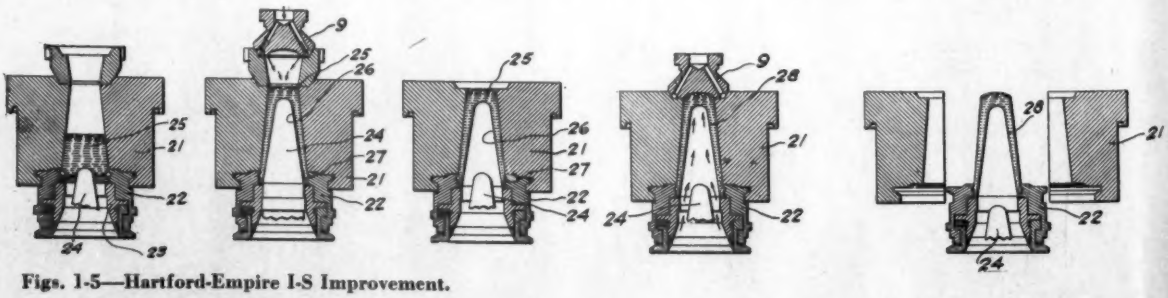
Patent No. 2,402,708 is the invention of Stewart, Reek and Kelly, who assigned their invention to Kelly Foundry and Machine Company. This patent is a division of their prior patent, No. 2,329,012, issued September 7, 1943. The patent relates to apparatus for cooling the molds of paste mold machines.

Fig. 7 shows the invention as applied to the machine shown in Patent No. 2,329,012 which has been issued to these inventors. The present patent shows a table 46 carrying three sets of mold halves 54 and 55. A pump is provided to supply cooling fluid through a pipe 223 to a nozzle 223^1. This fluid is directed against the molds and runs off through openings in the table 46 to a collecting pan 53 from which it is drained to a container in the base of the machine where the sediment settles out. The pump then recirculates the fluid. Due to the large area exposed, the fluid is cooled when it returns to the pump.

Miscellaneous Processes

Patent No. 2,402,387 was assigned to Owens-Illinois Glass Company by the inventors, John E. Ferguson and Cecil W. McCreery. This machine seals the halves of glass brick together while atmospheric air is displaced by dry air. Any moisture enclosed in a brick will condense on the inner surface and spoil the appearance of the brick.

The machine is of the turret type having six heads which advance intermittently to the working stations. These stations are 1, a loading station; 2, 3 and 4, heat-



Figs. 1-5—Hartford-Empire I-S Improvement.

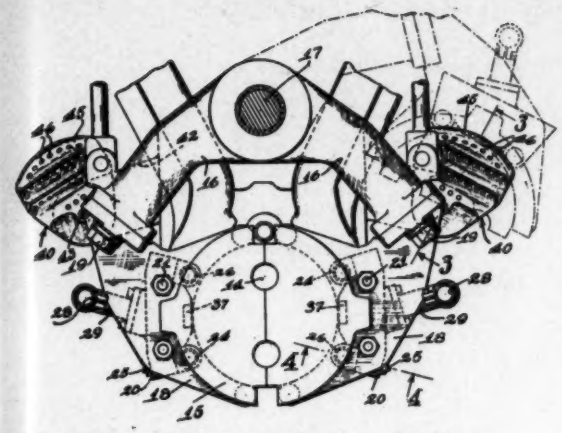


Fig. 6—Mold Cooling Device for Owens Machines.

ing stations where the edges of the two halves are softened for sealing; 5, sealing station; and 6, unloading station where the completed brick is removed. Fig. 8 is an elevation of the sealing station.

The several heads are mounted on a carriage 10. The upper half B of the block is carried by a holder 12 and the lower half B^1 by a holder 13. At the time the head reaches the sealing station shown in the figure, the edges of the halves have been softened at the three preceding stations ready to be welded together. The lower holder 13 is arranged to be moved up by means of an air cylinder 14. The operation of this cylinder may be controlled by a hand-operated mechanism such as shown in Patent No. 2,238,153 to Blau, or automatically as shown in Patent No. 2,244,291 to Easters.

Dry air is blown between the halves to sweep out the moist atmosphere by a nozzle 15 mounted on an adjustable arm 21. The arm is carried by a bracket 20 fixed on an arm 17 pivotally mounted on a post 16. A handle 16^a is provided for swinging the nozzle toward and from the work. A particular construction of the nozzle is described which is said to be highly effective in removing moist air. The direction of discharge of the nozzle can be adjusted by a handle 34.

Air to the cylinder 14 for raising the lower half, is controlled by a cam 50 on the carriage 10 which actuates a poppet valve 47. This valve operates another valve 44 which raises the lower half of the block and also turns on the supply of dry air to the nozzle 15. In order to prevent too much cooling of the lower half as it is raised, a shield 36 is provided. A valve 51 is engaged by a boss 53 to reverse the operation of the air cylinder 14 and lower the holder 13 after the seal is completed.

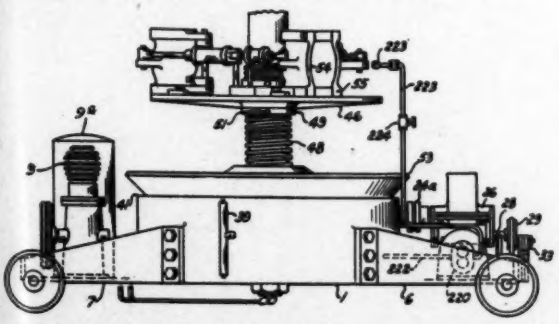


Fig. 7—Device for Cooling Paste Molds.

Patent No. 2,402,452 is a machine for burning the moil off from tumblers and forming a bead on the edge of the ware. It is an invention of Carl W. Schreiber and assigned to Owens-Illinois Glass Company. It is a continuation of an earlier patent application. Most burning-off machines let the moil drop away by gravity, but this machine lowers the ware away from the moil which is held in a chuck.

Fig. 9 shows a base 15 carrying a frame 16 in which a slide 19 is mounted for vertical movement. This slide carries a chuck 22 and burner 23. The chuck is in the form of a cup 24 carried by a bearing 25 to permit rotation. The bearing includes a sleeve 26 and a tubular shaft 27. Vacuum to hold the ware in the chuck is provided by a pipe 30. An ejector rod 33 is inside of the shaft 27.

The chuck 22 is rotated by a pair of gears 34 driven

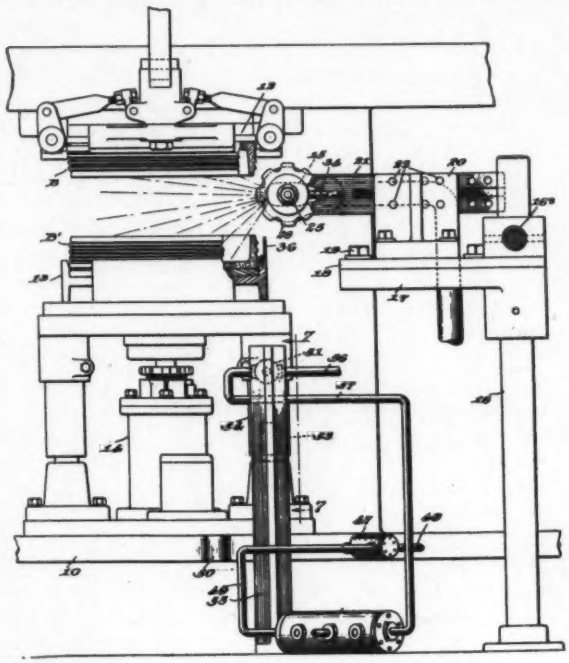


Fig. 8—Owens Brick Sealing Machine.

by a shaft 35 having bevel gears 36 and 37 connected through a speed reducing unit 39 with a motor 40.

The burner 23 is fed by a gas pipe 44 which is on continuously and an oxygen pipe 45 which is opened and closed by a valve 46.

The moil gripping chuck 47 comprises a pair of jaws 48 mounted on a head 50 which is rotated by gears 53 and 54. The gear 54 is fixed on the shaft 35 which drives the chuck 22 so that the chuck and the jaws 48 rotate at the same speed. The jaws are opened and closed by a push rod 60 within the shaft 35 actuated by a bell crank 61.

When the ware is placed in the chuck as shown in the figure, the chuck is raised to position the moil within the jaws 48 by the operation of a rack 63 on the slide 19, gears 64, 65 and 67, and a rack 68. This rack is reciprocated at the proper time by a cam 75. An adjusting screw 76 is provided to adapt the machine to ware of different heights.

A series of cams mounted on the shaft 78 act to give

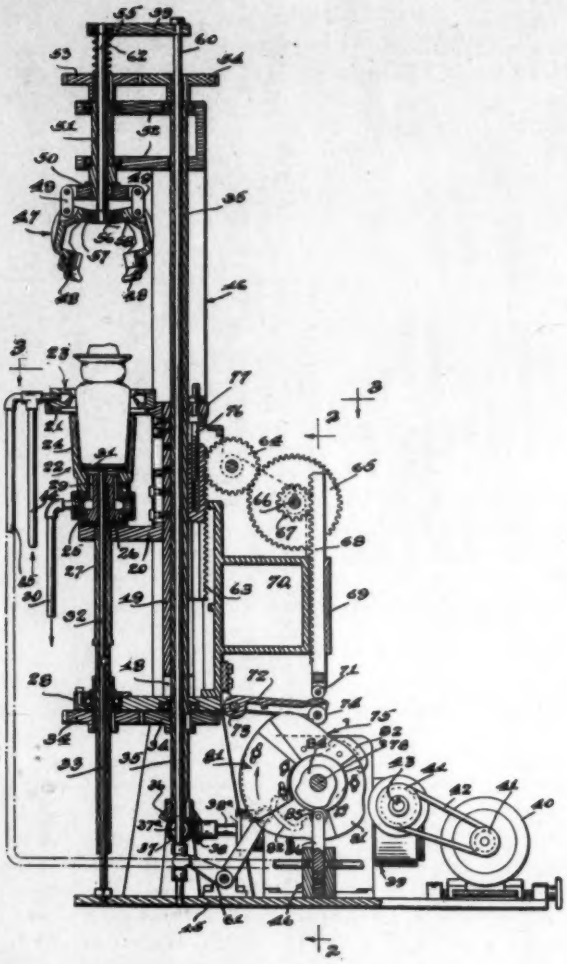


Fig. 9—Owens Burning-off Machine.

the desired movements and to open and close the oxygen valve 46. The arrangement is such that the suction bottom plate 31 is raised to receive the ware and then the chuck and burner are raised to lift the moil into position to be grasped by the jaws 48. The jaws and chuck then rotate together while oxygen is supplied to the burner. After the glass has softened to the desired extent, the chuck is lowered to separate the moil and the ware. The burner then forms the bead on the edge of the tumbler. Oxygen is then turned off and the chuck continues to descend while the bottom plate is stationary thus leaving the finished article above the top of the chuck. The bead thus formed is free from lumps so often found when the moil and the ware are separated by gravity.

Patent No. 2,402,864 is for a paint capable of withstanding high temperatures, for example, such as stacks. It is the invention of Paul Zurcher who assigned it to Continental Oil Company of Ponca City, Oklahoma. This paint is said to resist settling for long periods and to be applicable either by brush or by spray. Various coloring pigments may be incorporated. Two examples of this paint are as follows:

Vehicle 56%:	*No. 1*	Per cent
Resin		10
Vegetable oil		40
Drier and volatile		50
Pigment 44%:		
Blue lead		90
Zinc chromate		10

	No. 2	Parts by weight
Pigment 44% by weight:		
Blue lead		34
Litharge		12
Red iron oxide		27
Boric acid		27
Vehicles 56% by weight:		Per cent
Linseed oil		100

Patent No. 2,402,924 shows a tube or rod drawing machine and it has been assigned by the inventor, Harold H. Snyder, to Forter-Teichmann Company. The machine shown is, in general, of the Danner type, but several novel features have been incorporated.

Fig. 10 is a section through the machine. A mandrel 1 projects through the wall 2 of a furnace where it receives a stream of molten glass G which is drawn off as a tube T. The mandrel is carried by a hollow shaft 23 splined to a bushing 24. The projection of the mandrel into the furnace is determined by a hand wheel 27. An electric motor rotates the mandrel through a gear 17 and a worm 22. All of this mechanism is mounted in a water cooled shell 10 arranged to pivot in blocks 9 projecting from a platform 4. A threaded stem 12 carrying a threaded gear 14 determines the angle of the mandrel. A nut 15 is provided for adjusting this angle. Obviously, the machine may be driven by any kind of a motor.

Among the advantages claimed for this invention are that the parts subject to high heat may readily be replaced and adjustments which will remain fixed may be made easily.

Patent No. 2,403,224 disclosed an electrode for use in television and the method of making it. This patent was

(*Continued on page* 421)

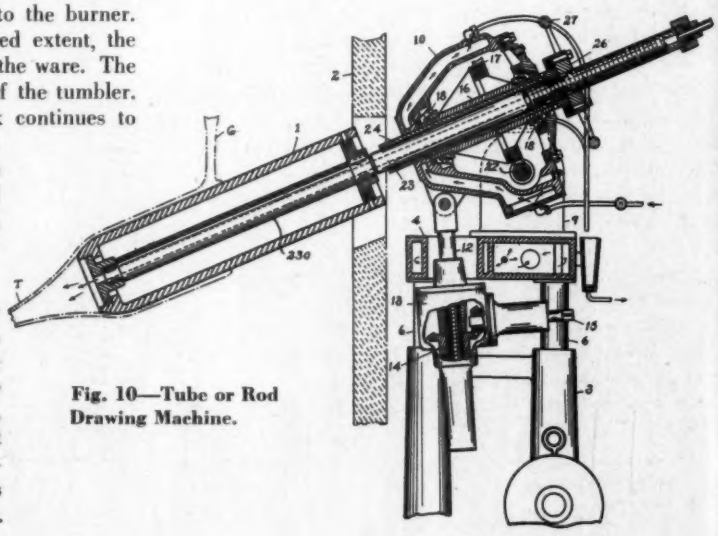


Fig. 10—Tube or Rod Drawing Machine.

GJ Research Digest

Practical Interpretations of Glass Technology

Latent Milling Marks on Glass

Before World War I, it was the usual practice to shape optical parts by lapping with loose abrasives. This method has been replaced by surface grinders which are tooled with diamond charged wheels. There is no visible difference in the final optics between those prepared by milling and those treated by the classical method of grinding with loose abrasives when the optics are first prepared. However, it was found that certain milled pieces, when they were acid polished, returned with a fine brilliance, but were sadly marred by long curving lines of pits following the trajectories of the diamonds in the milling tool.

F. Shirley Jones (*Journal of the American Ceramic Society*, April 1946) reports on the results of an investigation made to determine the cause of such latent milling marks. It is well known that diamond scratches made for the purpose of cutting glass cause one vertical and two horizontal fractures, which chip out glass near the surface. Milling with a diamond charged wheel makes use of the horizontal chipping. Small pieces are also spalled out when penetrating cracks intersect. That the vertical fracture, which on a larger-scale phenomenon is three or more times deeper than the horizontal pitting, would still remain in miniature in milling, might not be unexpected from apriori considerations. No attempts, however, are made in the fine grinding which follows milling to insure that all such effects have been removed other than a visual observation that the characteristic milling marks are no longer visible. That their disappearance can be illusory is demonstrated by Jones.

Pieces of glass were milled and fine ground under known conditions and then etched. Before etching, the glass slabs were studied under the polarizing microscope with magnifications up to 560. No evidence with ordinary or polarized light was detected of the latent milling marks themselves or of a strain pattern connected with them; hence, the flows were truly invisible. On etching, the latent milling marks appeared.

One interpretation of this phenomenon would suggest a certain amount of surface flow during the grinding, the material deposited in the residual milling marks reacting differently to changes in chemical and physical conditions from the mass of glass. Another would suggest that the latent milling marks are vertical fractures, the walls of which are in optical contact. In fact, surface flow during grinding, as well as vertical fractures, could exist together. This experiment showed that milling influences the glass to a considerable depth below the observable region. Glass milled in this manner necessitates a supplementary grinding which will remove at least 0.005 in. to assure the complete removal of all traces of the original milling.

The same results were obtained with glass slabs which were milled, fine ground and then optically polished.

Thin polished slabs (under pressure) were found to break at times along a milling mark whose presence is later verified by etching.

It was concluded that each of the fine pieces of diamond in a milling tool act in a way similar to a glazier's diamond cutting glass. The horizontal chipping removes the glass, but there remains a vertical fracture two to three times as deep as the chips. The sides of the fracture are probably nearly all in optical contact. Unless glass is removed by grinding or polishing to a depth greater than the small vertical fractures which result from the milling, these fractures remain as an invisible flaw in the glass and tend to lower its tensile strength and weatherability. (It is interesting to note that these results give additional confirmation to the invisible (visually) flaw theory of glass fractures and show the importance of knowing the exact condition of the glass surface.)

Notes on Silicate Analysis: Elimination of Excess Hydrofluoric Acid

In the analysis of insoluble silicates, such as glass, a convenient method of decomposing the sample is by the use of hydrofluoric and perchloric acids when silica is to be determined on a separate sample or by difference. To decompose a soda-lime glass and remove the silica, a liberal excess of hydrofluoric acid must be present. While the silica is being removed as silicon tetrafluoride, the other glass constituents go into solution in the hydrofluoric-perchloric acid mixture. After the silica has been removed, a considerable quantity of hydrofluoric acid remains.

The presence of this excess fluorine can cause trouble during the determination of constituents, such as aluminum, calcium and magnesium. For example, fluorine prevents the complete precipitation of aluminum in the R_2O_3 group. Calcium will partially precipitate in the R_2O_3 group as calcium fluoride and the determination of magnesium is subject to error due to the presence of any incompletely precipitated aluminum.

Osthaus (*Journal of the American Ceramic Society*, April 1946) reports on a procedure for the elimination of the excess by hydrofluoric acid. The detailed procedure is as follows: Place 2.5000 gram of powdered glass in 300 ml. platinum dish. Moisten with water and add 10 ml. of 70 per cent perchloric acid and 25 ml. of 48 per cent hydrofluoric acid. Place the dish on a steam bath and swirl the contents occasionally. After evaporating to a small volume, transfer the dish to a hot plate. Continue heating until the sample is in solution and the silica is driven off. Add more hydrofluoric acid if necessary. After solution is complete, evaporate the contents of the dish to small volume. Wash down with 5 ml. of perchloric acid and add 30 to 50 mg. of c.p. silicic acid (Baker's e.p. $SiO_2 \times H_2O$ powdered). Continue fuming until solids begin to appear. Cool the dish and rinse down with water. Dilute to 100 ml. If the particles of silicic acid have completely disappeared, hydrofluoric

(*Continued on page* 406)

GLASS DIVISION COMMITTEE DEVELOPS PROPOSED STANDARDIZED GLASS DEFINITIONS

The Committee on Classification and Nomenclature, composed of five members of the Glass Division of the American Ceramic Society, has recently completed the first phase of its work on definitions of certain terms which it is felt should be standardized in usage in American glass literature.

This Committee, headed by H. H. Holscher of the General Research Laboratory of Owens-Illinois Glass Company, also has in its membership J. E. Duncan, Pittsburgh Plate Glass Company; H. R. Lillie, Corning Glass Works; A. K. Lyle, Hartford-Empire Company, and S. R. Scholes of the New York State College of Ceramics.

In a recent letter sent to the membership of the Glass Division, Mr. Holscher stated that his Committee had reached general agreement among themselves concerning preliminary definitions and he requested criticisms and suggestions from the Division members on the list of definitions which accompanied his letter.

It was pointed out that while it was felt unlikely that all suggestions could be adopted, "every effort would be made to make the proposed standardized definitions as universal in application as possible". It is planned that when all ideas have been submitted, the Committee will hold a meeting with a view to adopting as many of them as is feasible.

Following is the list of definitions submitted to the Glass Division for consideration:

Softening Point. The temperature at which a uniform fiber, 0.5 to 1.0 mm. diameter and 22.9 cm. long, elongates under its own weight at a rate of 1 mm. per minute when the upper 10 cm. of its length is heated in a prescribed furnace [*Journal of the American Ceramic Society*, 10, 259 (1927)] at the rate of approximately 5°C. per minute. For a glass density near 2.5, this temperature corresponds to a viscosity of $10^{7.65}$ poises.

Annealing Point. The temperature at which internal stress is potentially relieved in fifteen minutes; that temperature at which the glass has a viscosity of $10^{13.4}$ poises. The upper end of the annealing range.

Strain Point. The highest temperature from which strain-free glass can be cooled quickly without introducing permanent strain. The temperature at which glass has a viscosity of $10^{14.6}$ poises is generally considered as the strain point. The lower end of the annealing range.

Deformation Point. That temperature observed during the measurement of expansivity by the interferometer method at which viscous flow exactly counteracts thermal expansion. Generally corresponds to a viscosity of 10^{11} to 10^{12} poises.

Liquidus Temperature. The minimum temperature at which a molten glass can be maintained without the separation or formation of a crystalline phase.

Cord. An attenuated glassy inclusion possessing optical and other properties differing from the parent glass.

Working Range. The range of surface temperature in which glass is formed into ware in a specific process. The "upper end" refers to the temperature at which the glass is ready for working (generally corresponding to a viscosity of 10^3 to 10^4 poises), while the "lower end" refers to the temperature at which it is sufficiently viscous to hold its formed shape (generally corresponding to a viscosity greater than 10^6 poises). When the process is not specified, the viscosity range is assumed to be 10^4 to $10^{7.65}$ (softening point) poises.

Fusion. The thermal process by which the batch charge is completely converted into glass free from undissolved batch. Generally called "melting".

Melting. See "Fusion".

Fusion Temperature. The range of furnace temperature within which fusion takes place at a commercially desirable rate, and at which the resulting glass generally has a viscosity of $10^{1.5}$ to $10^{2.5}$ poises. Without reference to commercial melting and for purposes of comparing glasses, it is assumed that the glass at fusion temperature has a viscosity of 10^2 poises.

Fining. The process by which the fused glass becomes free from undissolved gases. Certain usage of the term also implies the development of a commercially homogeneous glass.

Durability. The lasting quality (both visible and chemical) of a glass surface. Frequently evaluated, after prolonged weathering or storing, in terms of chemical and physical changes in the glass, or in the contents of a vessel.

Setting Rate. A qualitative term depending inversely on the time required for the glass surface to cool between the limits of the working range. Sometimes referred to as "cooling rate".

CORNING MAKES NEW APPOINTMENTS

Corning Glass Works recently named Russell Brittingham as Manager of the Technical Products Division. Mr. Brittingham was formerly assistant to the Manager. In his new post, he succeeded William C. Decker, who was elected President of the company in April.

A member of the Corning staff since 1944 when he joined the company in an administrative capacity in the laboratory, Mr. Brittingham later assisted in coordinating production and sales operations of the Technical Products Division.

The company also announced the appointment of Robert J. Black as an assistant to Harry M. Hosier, Vice President and Director of Industrial Relations. Mr. Black will assist Mr. Hosier in coordinating special phases of the company's industrial relations program.

Mr. Black was formerly associated with Batten, Barton, Durstine & Osborn, Inc., advertising agency, which has aided Corning Glass Works on many of its problems and has been connected with its advertising for the past ten years.

JESSOP NAMES CARBIDE & CAST ALLOY DIVISION MANAGER

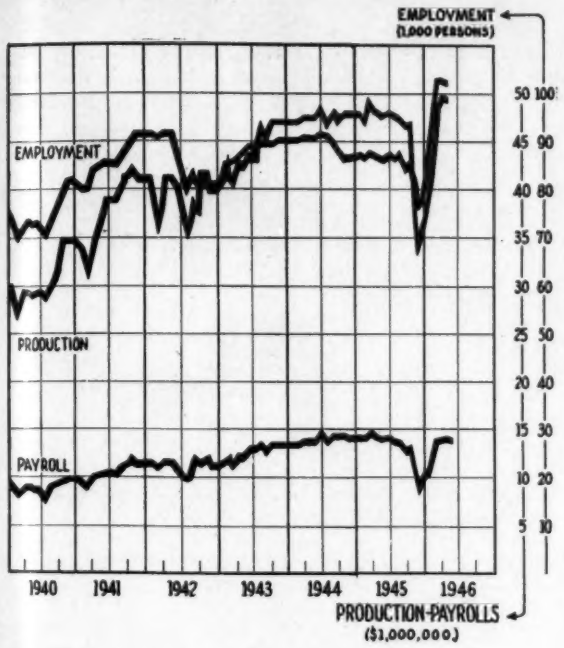
The Jessop Steel Company has named Joseph N. Peters as Manager of the Carbide and Cast Alloy Division.

Mr. Peters attended Massachusetts Institute of Technology and later was employed by the Callite Tungsten Products Corporation, Allegheny-Ludlum Steel Corporation and the Universal Cyclops Corporation.

In 1945, he joined the Jessop Steel Company's staff. In his present capacity, Mr. Peters will supervise the production and sale of tools, dies and wear resistant parts made from sintered and hot pressed carbides and cast non-ferrous alloys.

CURRENT STATISTICAL POSITION OF GLASS

THE GLASS INDUSTRY'S INDEX



Activity in the glass industry during May 1946 dropped about 2 per cent according to the Production Index. Estimated production during the month was $49,000,000, as compared with $50,000,000 the preceding month. Production during May last year was estimated to be $47,000,000—about 4 per cent below the corresponding month this year. The estimated 5-month production ending with May 1946 is $235,000,000, as compared with $238,000,000 during the same period in 1945.

Employment and payrolls: The number of persons employed during May 1946 dropped slightly from 102,000 persons employed during April to approximately 101,500 persons. During May 1945, employment was estimated to be 86,600.

Payrolls also dropped slightly for the month of May 1946. The Index indicates an approximate $13,300,000 paid out during May as compared with $13,600,000 paid during the preceding month. May 1945 payrolls were $13,000,000. For the first five months of 1946, glass manufacturers have paid out about $54,000,000 in salaries. During the corresponding period in 1945, $70,000,000 was paid out.

Glass container production during June 1946 rose slightly, according to figures released by the Bureau of Census. Production for June was 8,991,276 gross, as compared with 8,960,660 gross produced during April. Production during June 1945 was 8,702,164 gross which is about 3 per cent under June this year. Total glass container production for the first half of 1946 is 56,185,073 gross in comparison with 50,860,610 gross produced during the corresponding period in 1945.

Shipments of glass containers dropped about 5 per cent during the month of June. The figure reported is 8,874,333 gross, as compared with 9,414,367 gross shipped during April. Shipments during June 1945 were 9,054,635 gross—or about 1 per cent over June this year. Total shipments during the January-June 1946 period have reached 56,588,373 gross. Shipments during the same period in 1945 were 52,450,567 gross.

Stocks on hand at the end of June were 3,728,888 gross. This is slightly above the 3,642,641 gross on hand at the end of May. June 1945 inventories were 3,985,804 gross.

Plate glass production, according to the Hughes Statistical Bureau, was 16,315,599 sq. ft. during the month of June 1946. This figure represents an approximate 13 per cent drop from the 18,862,864 sq. ft. produced during May. June 1945 production was reported to be 6,081,137 sq. ft. which is a good deal below June

GLASS CONTAINER PRODUCTION AND INVENTORY

(All figures in gross)

		Production June 1946	*Stocks June* 1946
Foods; Medicinal & Health Supplies; Chemicals, Household, Industrials, Toiletries & Cosmetics	Narrow Neck	3,010,725	1,679,608
	Wide Mouth	3,041,669	999,333
Dairy Products		252,837	119,255
Home Canning		285,829	244,558
Beverages, Returnable		702,293	321,425
Beverages, Non-returnable		.....	.....
Beer, Returnable		426,558	113,157
Beer, Non-returnable		51,599	16,111
Liquors		787,088	148,092
Wines		341,676	66,612
Packers' Tumblers		91,002	20,737
Total		8,991,276	3,728,888

GLASS CONTAINER SHIPMENTS

(All figures in gross)

Narrow Neck Containers	*June* 1946
Foods	864,565
Medicinal & Health Supplies	979,416
Chemical, Household, Industrials	565,299
Beverages, Returnable	652,698
Beverages, Non-returnable	.....
Beer, Returnable	365,817
Beer, Non-returnable	48,847
Liquors	749,938
Wines	309,058
Toiletries & Cosmetics	515,743
Sub-Total (Narrow)	5,051,381
Wide Mouth Containers	
Foods	2,410,592
Dairy Products	280,369
Home Canning	346,180
Medicinal & Health Supplies	266,004
Chemical, Household, Industrials	97,258
Toiletries & Cosmetics	137,649
Packers' Tumblers	91,023
Sub-Total (Wide)	3,629,075
Total Domestic	8,680,456
Export Shipments	193,877
Total Shipments	8,874,333

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this year. Total plate glass production thus far in 1946 is 91,190,077 sq. ft. which is considerably over the 48,431,127 sq. ft. produced during the first half of 1945.

Automotive tumbler production for the month of June rose about 23 per cent to 7,388,960 dozens. Production during May was 4,978,089 dozens. The June figure also represents an increase of about 21 per cent over the 6,091,147 dozens produced during that month in 1945. Shipments during June 1946 reached a total of 6,347,476 dozens, which represents an approximate 5 per cent drop from shipments in May which were reported to be 6,705,600. June 1945 shipments were 6,279,716 dozens. Stocks on hand at the end of June were 4,919,876 dozens. At the end of May, they were 3,936,676 dozens.

Table, kitchen and household glassware: Manufactures' sales of machine-made table, kitchen and household glassware for the month of June 1946 dropped about 14 per cent to 3,846,905 dozens from the 4,512,616 dozens reported for May. June 1945 sales were 3,101,554 dozens. Total sales during the 12-month period ending June 1946 have reached 42,788,278 dozens.

RESEARCH DIGEST . . .

(*Continued from page* 403)

acid is undoubtedly not completely eliminated in which case add more silicic acid and return the dish to the hot plate. After eliminating the fluorine, filter the diluted solution through a No. 40 Whatman paper into a 250 ml. beaker and thoroughly wash the dish and paper, first with hot diluted hydrochloric acid (5+95) and finally with hot water. Discard the filter paper. Precipitate the R_2O_3 group with ammonium hydroxide using methyl red as an indicator. Filter through a No. 41 Whatman paper and catch the filtrate in a 250 ml. volumetric flask. Wash the precipitate four times with several mls. of hot 2 per cent ammonium chloride. Make up to volume and use aliquots for the other determinations. Ignite the precipitate in a tarred platinum crucible. Cool the crucible and cautiously add a few drops of water to moisten the oxides. Add a few drops of 1-1 sulfuric acid and 1 ml. of 48 per cent hydrofluoric acid. Place on hot plate and drive off any silicic acid in the R_2O_3 precipitate. Evaporate to remove the acids, heat cautiously and then ignite to constant weight at 1000° to 1200°C. The percentage of R_2O_3 is found by multiplying the gain in weight by 100 and dividing by 2.5.

FERRO ENAMEL ADDS TO COLOR DIVISION STAFF

The Ferro Enamel Corporation has announced the addition of Orville O. Kenworthy to its Color Division staff. He has been with the Chemical Warfare Service Branch of the U. S. Army until recently.

A former Lieut.-Colonel, Mr. Kenworthy will engage in research and development work in his new position. His efforts will be devoted largely to the development of inorganic coloring materials for glass, pottery and plastics.

Prior to the war, Mr. Kenworthy was associated with B. F. Drakenfeld & Co., Inc.

NEW EQUIPMENT AND SUPPLIES

SILICONE LUBRICANTS USED IN CLEANING LABORATORY GLASSWARE

The many advantages to be gained through use of Dow Corning Stopcock Grease and Dow Corning High Vacuum Grease have been given up by some micro-analytical laboratories because of the difficulty encountered in removing the non-wetting film formed on laboratory equipment by these silicone lubricants. The best cleaning methods previously developed involved use of caustic solutions which has to be carefully watched to avoid etching the glass. Recently, however, a hydrocarbon solvent has been found which quickly and efficiently removes silicone films from laboratory glassware.

This discovery was reported by G. Constabaris of the Department of Chemistry of the University of British Columbia and has been verified in the laboratories of Dow Corning Corporation. He found that Dow Corning Stopcock Grease could be easily removed from laboratory glassware by decahydronaphthalene, also known as decalin or naphthalane.

The following procedure is recommended: 1) fill the apparatus with warm decahydronaphthalene (decalin) and allow to stand for two hours or more if necessary; 2) drain and rinse once or twice with acetone and dry with a stream of filtered air; 3) the decahydronaphthalene can be reused several times before it becomes effective.

Laboratory tests also indicated that only a very thin film of these silicone lubricants is necessary to provide effective lubrication and that judicious use of the greases and frequent cleaning should prevent surface contamination. It was also reported that the ordinary surface effects observed in burettes are for the most part due to dust in the atmosphere. Objectionable surface films were also observed in glassware lubricated with other types of grease.

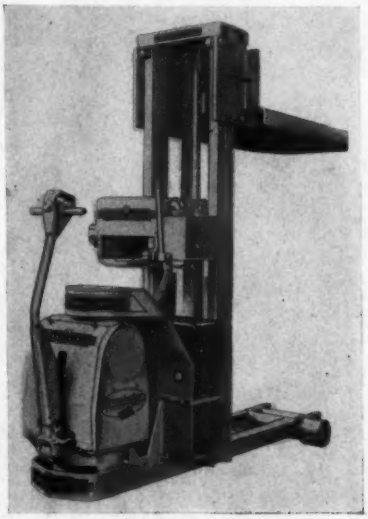
NEW MICRO X-RAY DIFFRACTION CAMERA

North American Philips Company, Inc., 100 East 42nd Street, New York, has announced the availability of a new Micro X-ray Diffraction Camera which permits study of minute sections and the charting of changes over microscopic areas. The new product is especially useful in research laboratories.

Designed to fit the Norelco X-ray Diffraction unit, the camera comprises a precision-machined body which is readily removable from its carriage for loading. Two specimen holders are provided, one comprising a special positioning and tensioning device for fibres, narrow strips or similar objects. The other holder utilizes a flat plate insert to accommodate microtomed sections, etc.

AUTOMATIC TRANSPORTATION COMPANY INTRODUCES TRANSTACKER

A new material handling unit, named the Transtacker, which does the work of a fork lift or high-lift platform truck where weight, size, speed or cost make the larger unit impracti-



cal, has been announced by the Automatic Transportation Company, Chicago, Illinois.

There are four Transtackers available. The one illustrated is the platform model for use with skid platforms. The other three are fork models built for all types of pallets.

The platform model will handle loads up to 4,000 pounds and will raise them 68 inches. Weight of this model is only 1,900 pounds and selling price is $1,800. The Transtacker's lift mechanism has all the advantages of regular lift trucks. It features a new hydraulic system and the same over-sized pump and motor. It is built on the chassis and drive unit of the Transporter, the company's motorized hand truck. It features finger-tip control which enables the operator to regulate direction, speed, lift and brake all with one hand.

WHEELCO PRESENTS PORTABLE PYROMETER

The Wheelco Instruments Company, 847 West Harrison Street, Chicago, Illinois, has announced a new Extension Type Portable Pyrometer.

The unit has been designed to permit a choice of plug-in angle extensions where a number of applications necessitate a universal instrument for measuring and checking temperatures requiring the use of different kinds of thermocouples.

A high resistance meter movement consists of baked, processed coils, supported by two lapped pivots resting in two highly polished sapphire resilient jewels. An Alnico No. 5 magnet, highly resistant to shock, heat, vibration and stray fields, provides increased ruggedness without a loss of sensitivity. Automatic compensation is a standard feature. A calibrated Briguet spiral automatically corrects every reading for variations in cold junction temperature. To protect the meter when the instrument is not in use, a shunt lever is provided which can be snapped into position with a simple thumb movement.

Plug-in extensions are available in either straight, 45 or 90° angle types. Adapters permit the choice of material and calibration of thermocouples. A 3 9/16" reflector scale prevents parallax errors in reading.

CATALOGUES RECEIVED

Fischer & Porter Company, Dept. 9M, Hatboro, Pa., has released a catalogue, Section 31-E, featuring a small size low cost Rotameter which has been developed specifically for purge line (Bubbler) service.

The bulletin gives illustrations, diagrams and tables relating to junior rotameters and C-Clamp rotameters. Also given, is a list of available catalogues relating to rotameters manufactured by the company.

Hammond Machinery Builders, Inc., Kalamazoo 54, Michigan, has issued Bulletin 310 introducing three new abrasive belt grinders.

The models are well illustrated and each carries descriptive material and specifications. Models featured are the VH-6, No. 5 and F-2. Other belt grinders are also covered briefly.

Ingersoll-Rand Company, 11 Broadway, New York 4, New York, has announced the publication of a 2-color, 16-page catalogue entitled, "Two-Stage Centrifugal Pumps".

The pumps described are used on dewatering service and as station pumps in mines, condensate service in power plants and as hydraulic pumps on elevator service.

The catalogue is well illustrated with cutaway views, types of drive and typical installations. There are tables of performance, dimensions and pipe friction, and a typical pumping problem is worked out in detail.

Chain Belt Company, Milwaukee, Wisconsin, has presented a 26-page bulletin on the complete line of Rex Belt Conveyor Idlers. Photographs, tables, charts, diagrams and cutaway views are used to illustrate and describe the items.

The first section of the book is devoted to the proper selection of idlers. Then follows a large two-page cutaway illustration showing details of construction of Rex idlers. After the description of the complete line of standard idlers, there is a section on special application idlers.

(*Continued from page* 394)

Tool and Valasek[8] determined the interval to be 7° to 9°. If the time definitions for strain point and annealing point (i.e., 4 hours and 15 minutes, respectively) are taken, the average interval for soft and hard glasses used in glass-metal seals is 8.75° C. The *annealing range* for various soft glasses run from 31° to 36°, with an average of 35°.

The next point on Fig. 12 as temperture increases is the *deformation point*, which is the temperature during an interferometer measurement of expansion[9] at which viscous flow exactly counteracts thermal expansion. The viscosity for this point is generally 10^{11} to 10^{12} poises.

The *softening point* is defined[10] as the temperature at which a uniform fiber, 0.5 to 1.0 mm. diameter and 22.9 cm. long, elongates under its own weight at a rate of 1 mm. per minute when the upper 10 cm. of its length is heated in a prescribed furnace at the rate of approximately 5° C. per minute. For a glass with a density of 2.5 this temperature corresponds to a viscosity of $10^{7.65}$ poises. The softening point is therefore a variable with respect to density, and softening points are not strictly comparable. This property of glasses, however, does not play a critical role in glass-metal seal theory.

The temperature range between the annealing point and the softening point is the *softening interval*. For soft glasses this range varies from 184° to 201°, with an average of 192° C.; for hard glasses the range is 207° to 266°, with an average of 235° C.

The temperature interval corresponding to viscosities of $10^{7.65}$ poises at one end and 10^{4} poises at the other end is generally the range in which glass is formed into various shapes, and this interval is the *working range* of a glass. The softening point is taken as the lower limit. The upper limit, called the *working point*, corresponding to a viscosity of 10^{4} poises, is the temperature at which a glass is ready for working.

The temperature at which a charge of batch is completely converted into glass is called the *fusion temperature*. For purpose of comparison between glasses it is somewhat arbitrarily decided that glass at the fusion temperature has a viscosity of 10^{2} poises.

While all of the above thermo-viscous properties have definite physical significance the purposes of the glass technologist are served satisfactorily if it is assumed that the viscosities corresponding to each point or range are arbitrarily chosen. This is sufficient to permit substitution of glasses in any process such as blowing, pressing, annealing, etc., which depends upon viscosity or change of viscosity. Thus, if a chart similar to Fig. 13 is made up, the strain point, annealing point, softening point, and all other thermo-viscous properties for all glasses will fall on horizontal lines which intersect the viscosity-temperature curves, and choice of a glass is dependent only upon temperature.

Physical Properties. Three physical properties only are listed in Table 2. Of these the coefficient of thermal expansion is the only property of direct interest in connection with glass-metal seals, and the value of the coefficient is relatively small in comparison with the importance of the total expansion or elongation curve. As a rough gauge in choosing glasses to match a particular metal it is safe in general to say that the difference in expansion coefficients between glass and metal should not exceed 10×10^{-7} per degree C., although this need not be true for certain external seals and is never true for thin-edge, thin-edge tubular, internal thin-walled tube, and certain ribbon seals.

(*Continued on page* 410)

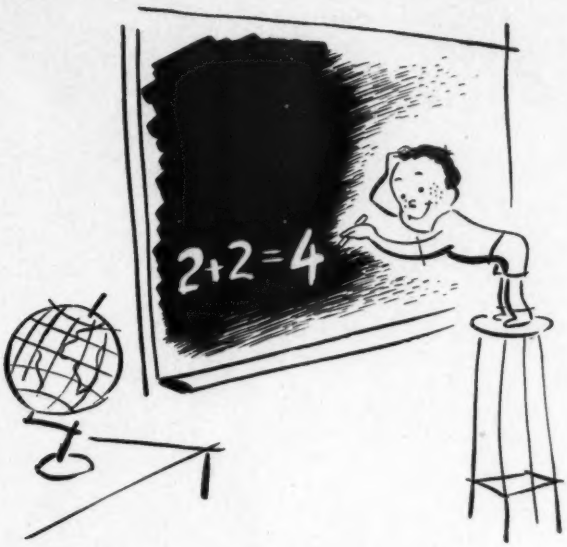
[8]Tool, A. Q. and Valasek, J., *Bur. Standards Bull. No. 358* (1919).
[9]Merrit, G. E., *Bur. Standards J. Res., 10*, 59-76 (1933).
[10]Littleton, J. T., *J. Am., Ceram. Soc., 10*, 259-63 (1927).

TABLE 2

THERMO-VISCOUS AND PHYSICAL PROPERTIES OF CORNING GLASSES

Glass	Thermal Expansion, cm/cm/° C.	Softening Point, ° C.	Annealing Point, ° C.	Strain Point, ° C.	Working Point, ° C.	Density, g/cc	Refractive Index, n_D	Young's Modulus, kg/mm²
001 (G1)	91×10^{-7}	626	428	397	970	2.85	1.542	8200
008 (G8)	92	696	510	475	1000	2.47	1.512	7400
012 (G12)	89	630	433	400	975	3.05	1.557	
005 (G5)	91	619	429	404		2.92	1.546	
024 (125BB)	96	607	425	397		2.97		
071 (1124A)	91	690	498	465		2.45	1.505	
1990 (1891Y)	127	496	359	334		3.47		
1991 (184ET)	128	539	393	366		3.18		
8160 (814KW)	91	627	433	399		2.98	1.553	
172 (172AJ)	41	915	712	672	1198	2.53	1.530	
3320 (371BN)	40	780	535	497		2.29	1.481	
703 (704BA)	43	784	557	519		2.31	1.485	
704 (705BA)	48	702	484	450	1080	2.24	1.480	
705 (705AJ)	46	703	496	461		2.23	1.479	6350
7052 (705FN)	46	708	480	442	1115	2.29		
706 (705AO)	50	690	495	463		2.25	1.482	
707 (707DG)	32	746	490	455	1100	2.13	1.469	5100
750 (750AH)	37	763	498	464		2.18	1.473	
772 (702P)*	36	755	518	484	1110	2.35	1.489	
774 (726MX)†	33	820	553	510	1220	2.23	1.474	6800
775 (705R)	41	704	467	431		2.19	1.474	
776 (720GO)	34	780	520	480	1213	2.23	1.473	
7991 (704EO)	41	800	565	529	1175			

*This glass called "Nonex".
†This glass called "Pyrex".



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GLASS METAL SEALS . . .

(*Continued from page* 408)

Density and refractive index are useful chiefly to differentiate between types of glasses whose identities are lost in stock room or factory.

A study of Fig. 14a will show clearly why the thermal expansion coefficient between room temperature and 300° C. can not be taken as a final measure of the match of glass to metal. An ideal relationship would be one in which the expansion curves for glass and metal are exactly superimposed or very closely parallel over the entire temperature range up to the softening point of the glass. Since nearly all metals and alloys have approximately straight-line expansions the ideal condition is approached only in the case of Kovar and several glasses designed for use with this alloy. The next preferable relationship is one in which the expansion curve for the glass coincides with or is closely parallel to the metal expansion curve and crosses the latter in the annealing range of the glass. This condition does not exist with any known glass-metal combinations. In practice, it is necessary to choose a glass and a metal whose expansions approach as nearly as possible to the above ideal relationship.

A word of caution is necessary in connection with this discussion of the expansivity of glass. It must always be remembered that all or nearly all properties of glass have true validity only when measured under equilibrium conditions. In other words, every measured property of glass, unless determined at equilibrium conditions, will have values which are dependent upon the thermal history of the glass. Hence the exact location of the elongation curve with respect to temperature is dependent upon the rate of heating and cooling. Fig. 14b is illustrative of what occurs when a glass is cooled at a

(*Continued on page* 412)

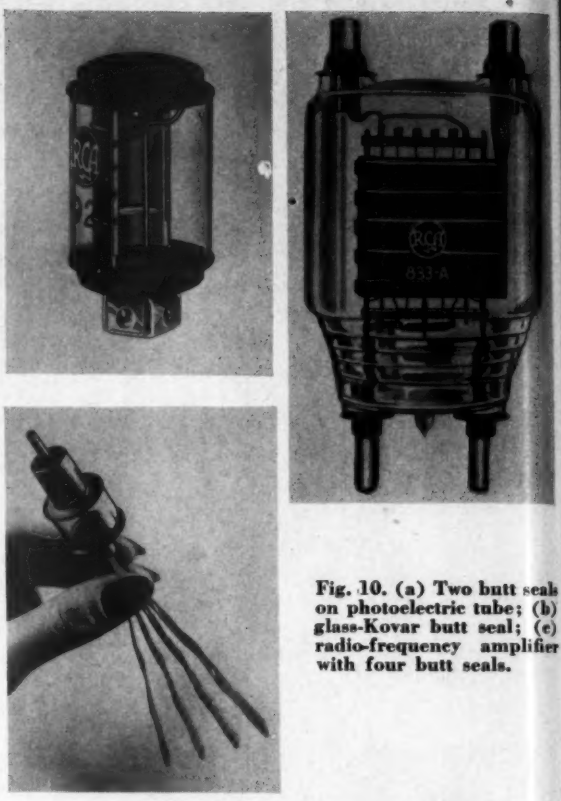


Fig. 10. (a) Two butt seals on photoelectric tube; (b) glass-Kovar butt seal; (c) radio-frequency amplifier with four butt seals.

TABLE 3

ELECTRICAL PROPERTIES OF CORNING GLASSES

Glass	Log Resistivity, ohms/cm³ 250° C.	300° C.	350° C.	Dielectric Constant	Power Factor x 10⁴ 25° C.	300° C.	400° C.
001 (G1)	9.075	8.015	7.125	6.6	16		
008 (G8)	6.355	5.710	5.170	6.1* / 7.2	106* / 90	1250*	
005 (G5)	6.900	6.120	5.470				
012 (G12)	10.075	8.935	7.98	6.6	16		
071 (1124A)	6.440	5.750	5.170				
172 (172AJ)	12.10		9.90				
3320 (371BN)	8.620	7.770	7.055	4.8*	36*	694*	
703 (704BA)	7.875	7.085	6.420				
704 (705BA)	9.725	8.755	7.945	5.0* / 4.8	24* / 18		332*
705 (705AJ)	8.310	7.475	6.770	4.9	33		
706 (705AO)	8.46		6.85	5.0	33		
7052 (705FN)	9.20		7.40				
707 (707DG)	11.175	10.055	9.115	3.7* / 4.0	12* / 6	23*	103*
750 (750AH)	10.015	9.030	8.205				
772 (702P)	8.815	7.935	7.200	4.2* / 4.7	28* / 27	121*	286*
774 (726MX)	8.150	7.350	6.675	4.1* / 4.6	54* / 46	347*	679*
775 (705R)	9.460	8.515	7.725				
776 (720CO)	9.36		7.80				
7991 (704EO)	8.525		6.970				
8160 (814KW)	10.560	9.370	8.375				

*Measured at 60 cycles by Miller, J. M. and Salzberg, B., *RCA Review*, *4*, 486-504 (1939); all other measurements by Corning Glass Works at room temperature and one megacycle.

CORHART SUGGESTS "A COMMON DENOMINATOR"

WHAT productivity should one expect from a given glass furnace?

If Tank "A" produces 45,000 tons of glass during one campaign and Tank "B" produces 84,800 tons, is Tank "B"'s performance the better?

Or if Tank "A" has a run of 500 operating days and Tank "B" a run of 600 days, which is the better performance?

Obviously other factors are involved, including the size and design of the furnace and the nature of the glass and product.

To compare one glass furnace with another of similar design and operation, a "common denominator" of tank production is obviously needed. It is apparent that *total tons produced* and *total days operated* are in themselves inadequate when comparing furnaces of different sizes.

AS a "common denominator" to reduce the operating factors to a comparative basis, we have, for some years past, been using the expression:

TONS, PER SQ. FT. OF MELTING AREA, PER LIFE

TONS = Total weight glass pulled, i.e., shear cuts
SQ. FT. MELTING AREA = Total area of melting end, not including the doghouse
LIFE = Period of one campaign

The use of this "Common Denominator" can be illustrated by the following four hypothetical examples: —

	Tank No. 1	Tank No. 2	Tank No. 3	Tank No. 4
Tank Melting Area (Sq. Ft.)	450	354	532	702
Total Tons Produced	49,150	43,112	59,158	69,390
Total Operating Days	655	658	633	653
Sq. Ft. per Ton per Operating Day	6.0	5.4	5.7	6.1
Tons, per Sq. Ft., per Life	109.2	121.7	111.2	98.8

Here are the performances of four tanks of various sizes, operating for different periods under different loads. Yet their performances are placed on a comparable basis by the use of the "Common Denominator" of TONS, PER SQ. FT. of MELTING AREA, PER LIFE.

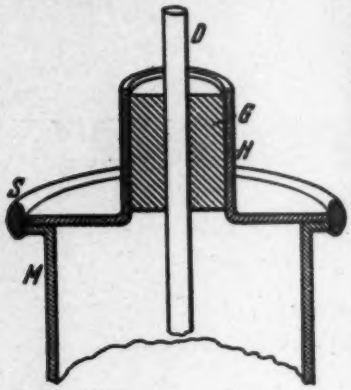
By using the above "common denominator," we believe that glass factory operators will find the analysis of their own furnace performances interesting and profitable.

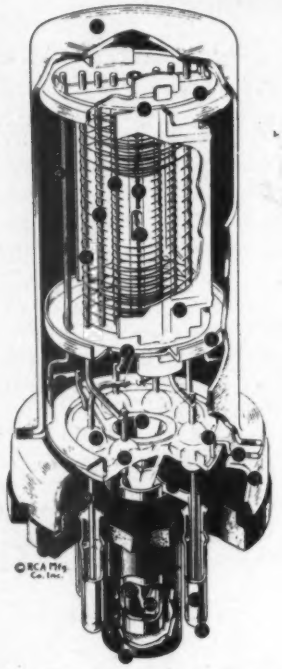
Corhart Refractories Company, *Incorporated,* Sixteenth and Lee Streets, Louisville 10, Kentucky.

QUALITY ECONOMY ENDURANCE

CORHART ELECTROCAST REFRACTORIES

(*Continued from page* 410)





1 METAL ENVELOPE
2 SPACER SHIELD
3 INSULATING SPACER
4 MOUNT SUPPORT
5 CONTROL GRID
6 COATED CATHODE
7 SCREEN
8 HEATER
9 SUPPRESSOR
10 PLATE
11 BATALUM GETTER
12 CONICAL STEM SHIELD
13 HEADER
14 GLASS SEAL
15 HEADER INSERT
16 GLASS-BUTTON STEM SEAL
17 CYLINDRICAL STEM SHIELD
18 HEADER SKIRT
19 LEAD WIRE
20 CRIMPED LOCK
21 OCTAL BASE
22 EXHAUST TUBE
23 BASE PIN
24 EXHAUST TIP
25 ALIGNING KEY
26 SOLDER
27 ALIGNING PLUG

Fig. 11. (a) Eyelet type of combination seal; (b) button stem for metal radio tube; (c) structure of metal tube, showing location of button stem.

reasonably rapid rate from the softening point to the annealing point, held for a period of time x at this temperature, and then cooled at the previous rate. The curve falls from the softening point to *a*, drops to *b*, and then follows *bo* to room temperature. If held at the annealing point for time $x+y$ the curve follows *aco* to room temperature. If held for time $x+y+z$ the curve follows *ado* to room temperature. Similar behavior is observed if the glass is held at the strain point, as shown by Fig. 14c. If the glass is held at the annealing point, cooled, held at the strain point, and then cooled to room temperature the shape of the contraction curve is shown by *ab' b"o*, as in Fig. 14d. It is evident then that the proximity of the metal and glass expansion curves at any temperature is governed by the rate of heating or cooling of the seal. Therefore, the kind and magnitude of the stresses in the glass in such a seal may be varied in many instances by the thermal treatment to which the seal is subjected.

Quantitative values for the change in differential contraction for certain glasses and metals are given by Hull and Burger[11]. They found that the contraction in cooling from the strain point to room temperature was less by 120×10^{-6} cm./cm. when the glasses were cooled uniformly at the rate of 1° C. per minute to the strain point, held at that temperature for 15 hours, and then cooled at the rate of 1° per minute to room temperature.

If each point on an elongation-temperature curve were an equilibrium point (determined by holding at that temperature for a period of many hours) the above behavior would not occur. It is not feasible, however, to determine expansivities in this way. Nevertheless, because of this fact, when stresses in a glass-metal seal are calculated or postulated on the basis of a glass expansivity measured at a given rate of cooling, a correction must be made if the rate of cooling of the seal differs from that used in measuring the expansion.

In any proposed application of a given glass-metal combination, it is important to remember that many seals which are satisfactory at temperatures above zero are completely inadequate at temperatures below zero because of divergence of the expansion curves at the lower temperatures or because of modifications in the crystal structure of the metal.

Electrical Properties. Since nearly all glass-metal seals are destined for use in electronic or electrical equipment, it is necessary to give serious attention to the electrical properties of glass. Seals may fail by puncture through the insulating glass, by electrical leakage over the surface of the glass, or by electrolysis in the glass. Circuit characteristics, especially at the ultra high frequencies, are very often dependent upon the power factor and dielectric constant of the glass used as insulation. The particular use to which a glass-metal seal is to be put must therefore be known in detail before a choice of glass and metal is made.

Resistivity of a glass is generally the most important electrical property. The resistivity at room temperature, however, is of doubtful value. If the temperature to which a seal is to be subjected is known, then a comparison of the resistivities of several glasses at that temperature may decide a choice. If the temperature is

(*Continued on page* 414)

[11]Hull, A. W. and Burger, E. E., *Physics*, 5, 384-405 (1934).
[12]Hartshorn, L., *J. Inst. Elec. Engrs.*, *64*, 1152-90 (1926).

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(*Continued from page* 412)

TABLE 4
PHOTOELASTIC CONSTANTS (STRESS-OPTICAL COEFFICIENTS)

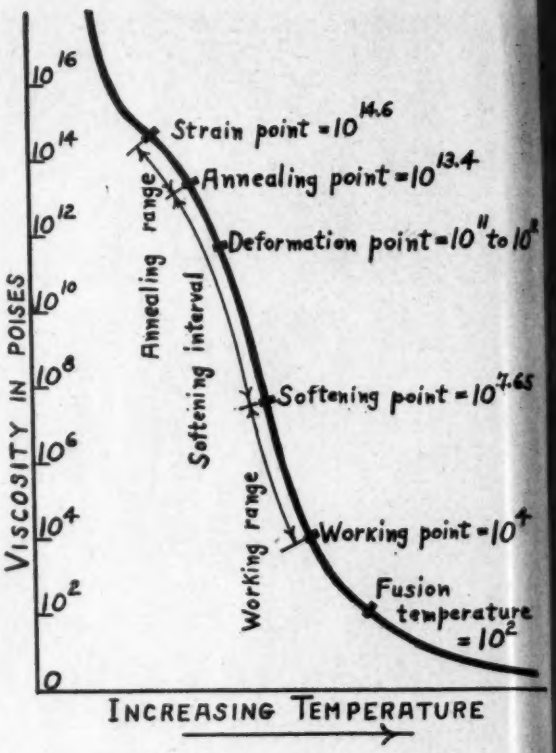
Glass	Brewsters* (1)	Brewsters* (2)	mμ/kg/cm²/cm (1)	mμ/kg/cm²/cm (2)
001 (G1)		2.78		2.73
005 (G5)	2.91		2.85	
008 (G8)	2.52	2.44	2.47	2.39
012 (G12)		2.53		2.48
705 (705AJ)	3.68	3.44	3.61	3.37
706 (705AO)	3.64		3.57	
707 (707DG)		4.45		4.36
772 (702P)	3.36	3.46	3.29	3.40
774 (726MX)		3.50		3.43
775 (705R)		3.53		3.60
3320 (371BN)	3.54		3.47	

*In the equation $R = 0.10752\ Cds$, if R is in m_μ, s in lbs. per sq. in., d in inches, then C is in brewsters.
(1) Measurements by Hull and Burger (see reference 11).
(2) Measurements by Corning Glass Works.

not known with certainty the slope of the line which is obtained when the logarithm of resistivity is plotted against the reciprocal of absolute temperature should be available. The values given in Table 3 are sufficient to permit plotting such a line for each of the glasses listed.

At a given frequency and voltage gradient in a dielectric, the power loss is proportional to the product of *dielectrical constant* and *power factor*[12]. This product

(*Continued on page* 420)



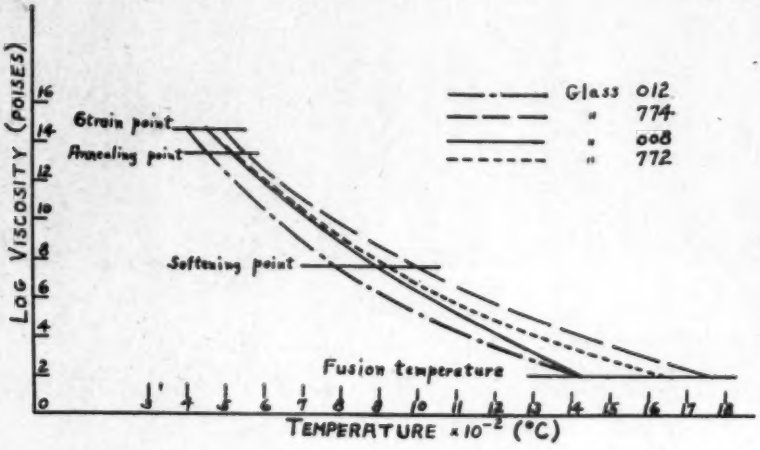
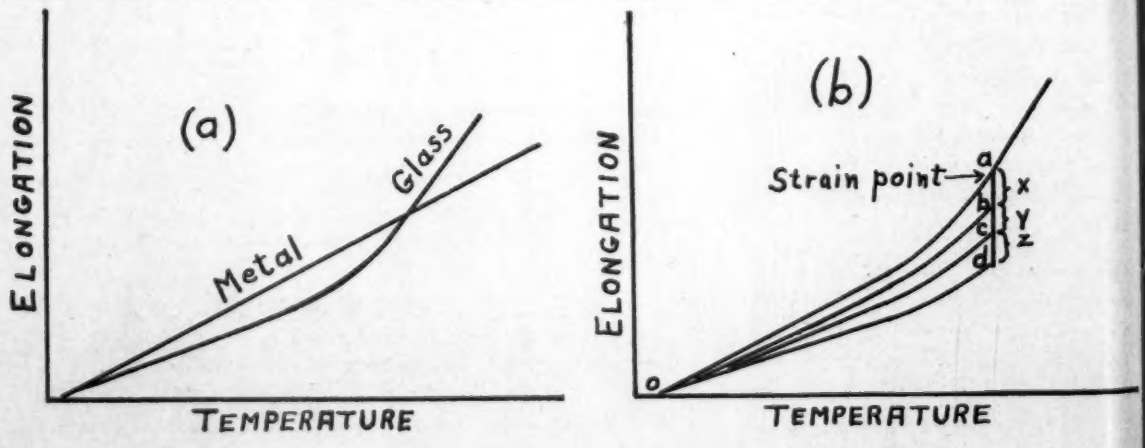


Fig. 12 (above). Thermoviscous properties of glasses.

Fig. 13 (opposite). Thermoviscous properties of two hard and two soft glasses.

Fig. 14 (below) (a) Expansion curves of glass and metal; (b) effect on expansion of holding at strain point. **Fig. 14 Continued on page 420.**



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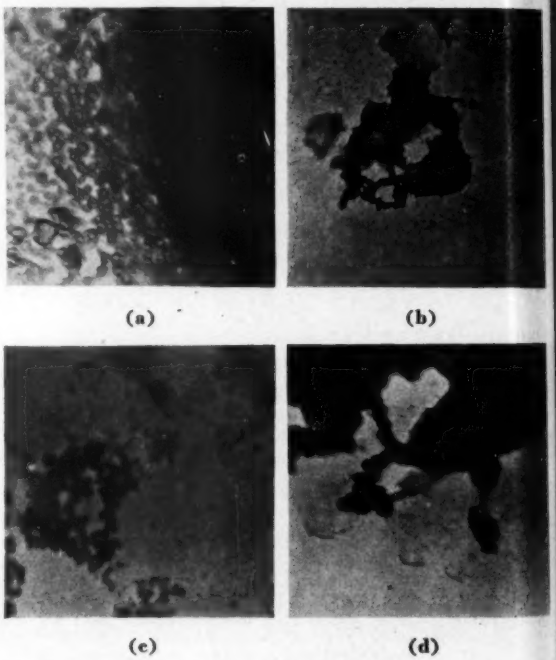
OBSERVATION OF GOLD PARTICLES IN GLASS . . .

(*Continued from page* 399)

Mention should be made of two preliminary investigations of interest in this study. The first of these investigations was completed before any trials were made on the soda-lime-silica ruby glass. It consisted in the observation of gold particles in a sodium silicate glass, of composition $Na_2O.2SiO_2$ with .0075% by weight of gold added. The ruby color was "struck" by holding the glass in a furnace at from 600°C to 900°C for several minutes, the glass was then dissolved in hot water, and finally the suspended gold particles viewed with the electron microscope. The test was successful in that the gold particles were clearly seen. Since this test was in the nature of a preliminary investigation merely to determine the feasibility of the method, no further work was done with sodium silicate glasses.

Since the electron beam does not penetrate even the thinnest films of glass obtainable, a sapphire-blue glass



(a) (b) (c) (d)

Figure 2. Electron microscope photographs with magnification of 15,500 x. (a) Glass treated at 600°C. No gold particles visible. (b) Glass treated at 700°C., showing gold particles approximately 60 millimicrons on an edge (1/400,000 inch). Typical ruby color. (c) Glass treated at 800°C. (d) Glass treated at 900°C. Glass is blue by transmitted light. Particles about 115 millimicrons on an edge (1/200,000 inch).

(St. Gobain) was prepared by long heat treatment so as to produce relatively large gold particles. After heat treatment the glass was ground extremely fine and viewed in the electron microscope. After several trials, particles of gold were observed sticking out of the edge of one of these minute particles (Figure 1), the glass particle itself being opaque. These gold particles are about 1250 millimicrons on an edge. The magnification of the photograph (Figure 1) is 10,000 diameters. For observation of smaller particles this technique did not seem promising and so was abandoned.

(*Continued on page* 418)

CORNING GLASS PLANT IN CANADA NEARS PRODUCTION

Corning Glass Works of Canada Limited, recently formed Canadian subsidiary of Corning Glass Works, is nearly ready to start production of Pyrex Brand ovenware, the first time such glass has been produced in Canada. At the factory at Leaside, suburb of Toronto, the 25-ton tank was lit on June 6, and the tank was expected to be full by June 24.

The plant is located in building number 14 of the Canadian government's Research Enterprises Limited, a company formed to make optical glass, radio tubes and radar and other wartime electronic and optical equipment. The building covers 100,000 square feet, is made of steel, brick and concrete with large areas of glass to afford good light in all parts of the building. Mezzanine floors have been built to the firing entrances of the furnace and to hold the two Surface Combustion lehrs and conveyors, adding approximately another 4,000 square feet of floor space. There is ample room in the building for construction of another glass tank, should that be necessary in the future.

Corning bought from Research Enterprises only the building and some adjacent land. The building had been used for radar construction during the war and did not contain the optical glass furnaces. These it is understood, are being kept as a standby in the Research Enterprises buildings being retained by the Canadian government. The floor area of the building bought by Corning is being equipped for storage of Pyrex ovenware, for packing of the ovenware, and a machine shop where the company will be able to produce its own molds from Canadian-made stainless steel castings. As much as possible of the equipment on the floor of the plant is being bought or produced in Canada, while a certain amount has had to be imported.

The Canadian company has built its own glass tank, as well as a 135-foot stack painted with silicone heat resisting paint, and an 85 foot silo. A two track railway siding has also been constructed to allow cars to unload raw materials close to the silo by means of a conveyor system which carries the materials to the top of the silo. Automatic mixing and feeding machinery has been installed, so that the plant can be producing 24 hours daily every day of the week. New oil tanks with 40,000 gallons capacity feed the furnaces.

General manager of the Canadian company is H. C. Bates, Canadian-born engineer who was at Corning, N. Y., from 1925 to 1940, came to Canada early in the war to assist in getting the government's optical glass plant into operation, and was appointed to the present position when Corning decided to form a Canadian company to meet demands of the Canadian market and some South American exports. Most senior men in the plant having to do with actual glass making are from Research Enterprises, optical glass department. It is expected that about 125 persons will be employed at the plant when it is in full production. The 40-hour week, with three eight hour shifts, is to be used for most of the employees.

• H. C. Bates general manager of the Leaside, Ontario Plant of Corning Glass Works of Canada, Ltd., has been made a Member of the Order of the British Empire in recognition of his outstanding work in the production of glass precision instruments during the war.

Left to right: W. R. Greer, Vice President; C. P. Lohman, Sales Manager; J. E. Eagle, Sales & Service Engineer, who will head the new division; Stan Hindes; and R. P. Welsh, who will direct research and development work of the new division.

PEMCO COMPLETES NEW GLASS COLOR PLANT

The Pemco Corporation has just announced the completion of their new plant which was built for the purpose of producing glass and ceramic colors. J. Eugene Eagle will head the new division.

The new plant is equipped with the latest developments in glass color making machinery and houses two enormous glass color laboratories staffed with skilled technicians, each of whom has had years of experience in the glass ceramic color field.

Officials of the company state that production is under way in the new plant and shipments are being made on colors for illuminating ware—sulfide resistant colors in both enamel and satin matt finish; colors for milk and beverage bottles—squeege colors, highly resistant to both acid and alkali; acid resistant syraying colors for dinnerware, cosmetic containers, general ware, etc.; and soft spray and squeege colors for tumblers, novelties, general ware, etc.

OWENS-ILLINOIS ANNOUNCES NEW APPOINTMENTS

Owens-Illinois Glass Company has announced the appointment of Roy B. Bradley and Don McAnally to the Sales Promotion Department to service the Drug and Chemical Industry Divisions.

Mr. Bradley, a registered pharmacist, has been named Divisional Merchandising Manager. He has been associated with E. E. Butman Drug Company, Winthrop Chemical Company, Johnson & Johnson and Charles Hubbard Drug Company.

Mr. McAnally, who has been assigned to publicity, was formerly in the newspaper business and joined the company in 1943 as an industrial editor.

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Jessop also makes molds and plungers cast from a special type stainless steel developed for the glass industry. Actual plant tests have proved that these molds and plungers increase production 10-20 times before replacement is necessary.

Write for further information on JESSOP'S stainless and alloy castings for the glass industry.

JESSOP STEEL CO.
MAIN OFFICE AND WORKS
WASHINGTON, PA.

OBSERVATION OF GOLD PARTICLES IN GLASS . . .

(*Continued from page* 416)

Results of Tests

Figure 2 shows electron microscope photographs, and Figure 3 gives the spectral transmission curves for the glasses produced by heat-treatment for 4½ hours at 600°C, 700°C, 800°C, and 900°C, respectively. The magnification in Figure 2 is 15,500 diameters.

In Figure 2 (a), no gold particles are visible. Minute

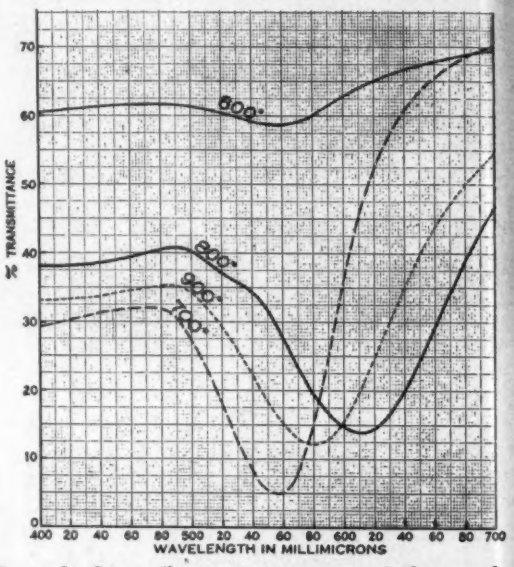

Figure 3. Spectral transmission curves of glasses referred to in Figure 2. (a) After treatment at 600°C. Pale violet color. (b) After treatment at 700°C. Ruby glass. (c) After treatment at 800°C. Blue glass. (d) After treatment at 900°C. Blue glass.

gold particles may exist in the glass treated at 600°C; indeed, the color of the glass indicates that they do exist. In any event, the particles would be so small that their detection and observation would be difficult. Those particles visible in Figure 2 (a) are either fluorides or, more probably, particles of glass that escaped solution by the hydrofluoric acid. Figure 3 (a) gives the spectrophotometer transmission curve for this glass, which appears a light violet color to the eye.

In Figure 2 (b) small gold particles are clearly visible in the lower left-hand portion of the photograph. They are seen as cubes, all about the same size. In the photograph the cubic crystals average about 1 mm. on the side. At a magnification of 15,500 this is equivalent to an actual particle size of slightly more than 60 millimicrons. Figure 3 (b) gives the spectrophotometer curve for this glass, which appears a ruby red to the eye.

Figure 2 (c) is included merely for the sake of completeness, for the photograph is not clear, due in large part to the vibration in the building at the time the photograph was taken. However, cubical tendencies are apparent in some of the particles. Figure 3 (c) gives the transmission curve for this glass, which appears blue by transmitted light, and a brownish "livery" color by reflected light.

In Figure 2 (d) the cubic gold particles are visible as an aggregation in the left central portion of the photo-

(*Continued on page* 422)

ROBERT STONE JOINS A.C.S.

Robert L. Stone has joined the staff of the American Ceramic Society as Technical Secretary, according to a recent announcement.

A graduate of Missouri School of Mines and Metallurgy, Mr. Stone received the degree of Bachelor of Science in 1934. He then entered North Carolina State College as Teaching Fellow in the Department of Ceramic Engineering. He received his degree of Master of Science in 1936. During the period 1936-1939, Mr. Stone was junior partner in the firm Greaves-Walker Engineers and was research ceramist for the Feldspathic Research Corporation.

During 1939 and 1940, Mr. Stone was research engineer and production manager of the Hales Manufacturing Company. He was appointed assistant professor at the New York State College of Ceramics in 1941 and returned to North Carolina State College later that year as associate professor. His most recent association was that of director of research at the Stupakoff Ceramic and Manufacturing Company.

EUGENE ROLLAND DIES SUDDENLY

Eugene Rolland, aged 61, passed away suddenly as the result of a cerebral hemorrhage. At the time of his death, Mr. Rolland was President of the Fourco Glass Company, Rolland Glass Company, Adamston Flat Glass Company and Harding Glass Company.

A native of France, Mr. Rolland came to this country with his parents in 1888. His father assisted in forming the Lafayette Glass Company. Eugene Rolland started working in the plant and became its President in 1905. In 1915, the family acquired the Peerless Glass Plant and formed the Rolland Glass Company.

In 1935, the Fourco Glass Company was formed. Associated with Mr. Rolland were Frank Bastin, Blackford Window Glass Co.; John B. Scohy, Scohy Sheet Glass Co.; and W. M. B. Sine of Adamston Flat Glass Co.

Mr. Rolland is survived by his widow, Mrs. Edmire Morel Rolland, a son, Morel, three brothers, Ernest J., Charles and Albert A., and a sister, Marie Rolland.

DIAMOND ALKALI TO CONSTRUCT TEXAS PLANT

The Civilian Production Administration has given its approval to Diamond Alkali Company for the construction of a $5,750,000 electro-chemical plant to be erected in Houston, Texas. The plant will manufacture chlorine, caustic soda and muriatic acid.

Construction on the 280-acre plant side is expected to begin shortly and the new plant will include eight buildings covering about 40 acres. The buildings will be constructed of steel with cement asbestos roofing and siding. It is expected that the new Houston plant will employ 200 persons for its initial operation.

PENN SALT MARKETS FLUORINE

The Pennsylvania Salt Manufacturing Company has announced that it has put fluorine, the most chemically active element known, on the market for the first time. The element is so active that it defied isolation for 73 years after its discovery 133 years ago.

Fluorine is a nearly colorless gas about 30 per cent heavier than air. It is ninth in the series of elements in the periodic table with an atomic weight of 19 and is the first element in Group 7, the halogens. Fluorine has only one valence, —1, whereas the other halogens are multiple valence elements. Its atomic structure consists of a nucleus having a positive atomic charge of 9, an inner shell of two negative electrons and an outer shell of seven negative electrons. One pound of the gas at room temperature would fill about 10 cubic feet.

The gas can be condensed below the critical temperature of —129° C to a liquid. Liquid fluorine boils at —187° C under one atmospheric pressure. In physical properties, fluorine resembles the fixed atmospheric gases, oxygen and nitrogen. It has an intense odor and toxicity of fluorine is said to be about the same as that of chlorine.

Fluorine reacts vigorously with most metals at elevated temperatures. It also reacts strongly with silicon-containing compounds; thus, it can support continued combustion of glass, asbestos, etc. In its reaction with hydrogen, fluorine gives off five and a half times as much heat as in chlorine's reaction with hydrogen.

Penn Salt announced fluorine is now available in steel pressure cylinders on a limited commercial basis for experimental use by manufacturers and researchers.

LEE UPTON JOINES BATTELLE INSTITUTE

To assist in an expanded program of research in glass technology, Lee O. Upton has been named to the staff of Battelle Memorial Institute. He will conduct research on various phases of the development of improved glasses and improved process for the manufacture of glass products.

Mr. Upton, a graduate of Pennsylvania State College, has been associated with glass research since 1939, and has worked with Bausch & Lomb Company and the Armour Research Foundation.

Research in the field of glass technology has been expanding steadily at Battelle Institute and recent studies have included investigations of factors involved in the production of selenium—and gold-ruby glass; the development of "hard" glasses for use in instruments and timekeeping devices; the development of opacifiers; work on glass compositions to achieve specific results; studies of the use of oxidizing agents in glass batches; an investigation of the improvement of refractories for glass melting pots; and the development of metal-glass seals.

GLASS METAL SEALS . . .

(*Continued from page* 414)

is known as the *loss factor* of the dielectric. The values of dielectric constant and power factor are given in Table 3 for certain glasses at one megacycle and in a few instances at 60 cycles. It must be remembered that both dielectric constant and power factor change, often considerably, with frequency and temperature[13].

Photoelastic Properties. Before a glass-metal seal is incorporated into an electron tube or other assembly, it is important to check the degree of strain in the seal. In many cases the stresses which exist at some temperature above or below room temperature must be known. By means of certain relations[14] which are well known in elastic theory, it is possible to evaluate the stresses in many types of glass-metal seals by using relatively simple photoelastic measurements. In order to translate such optical observations into terms of mechanical stress, it is necessary to know the value of the *photoelastic constant* (stress-optical coefficient)[15] for the glass in question. Table 4 gives the constants for a group of glasses commonly used in sealing to metals. The values are expressed both in brewsters and in millimicrons retardation per kilogram per square centimeter stress per centimeter thickness.

[13]Murphy, E. J. and Morgan, S. O., *Bell System Tech. J., 16* 1-20 (1937).

[14]Poritsky, H., Physics, *5*, 406-11 (1934).

[15]Monack, A. J. and Beeton, E. E., *Glass. Ind., 20*, 191 (1939).

PROPOSED SHIPPING CARTON RULES . . .

(*Continued from page* 398)

compression test standard may be useful as an ideal at which to shoot in order to develop the best possible carton from the materials available. However, the contents of the carton and the inner packing in many instances may be far more important as a measure of protection than the compression test of the empty carton. For example, a wood case showing extremely high top and end compression strength, filled with bottles without interior protection, would make a mighty poor shipping case, while a corrugated carton showing relatively low top and end compression strength with the proper interior packing would make a mighty fine shipping case.

Furthermore, according to Mr. Wells, it is impossible to set up one rule for compression testing that will insure a satisfactory container for all or even a large portion of the products packed.

As pointed out by P. A. Parker, Chief Packaging Executive of Anchor Hocking Glass Corporation, many of the methods proposed by the Committee became obsolete when machine production of glass replaced the old hand method of glass blowing.

That the design standards proposed by the Committee do not result in good performance standards was dramatically demonstrated by J. H. Toulouse, Chief Quality and Specifications Engineer of Owens-Illinois Glass Co.

By means of a moving picture, Dr. Toulouse showed actual tests of shipping containers made in accordance with the Committee's proposed rules in contrast with tests of shipping containers made in up-to-date designs, with less materials, and at lower cost.

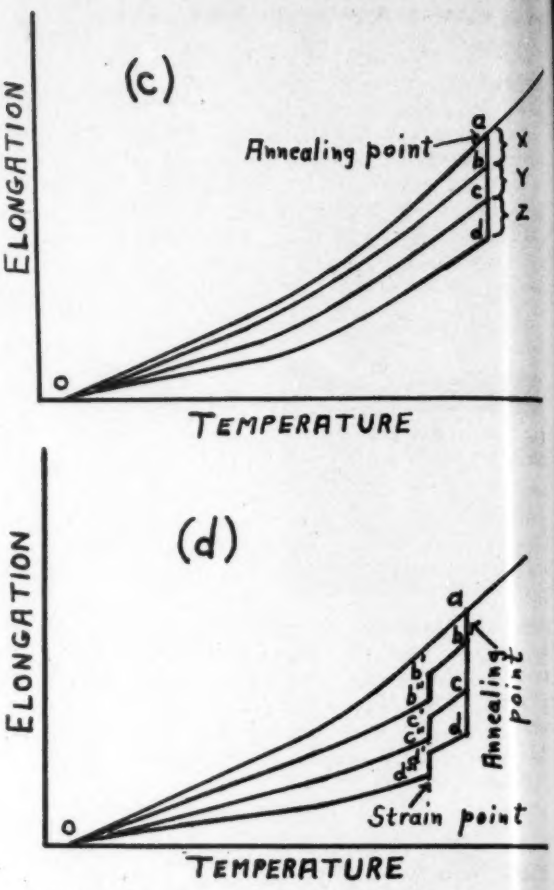

Fig. 14. (c) Effect on expansion of holding at annealing point; (d) effect on expansion of holding at annealing point followed by holding at strain point.

In the incline-impact or conbur test, the modern design was shown to afford 34 percent greater protection to glass bottles than the Committee's design. By revealing that breakage occurred almost exclusively at the end of the package opposite to the impact, the fallacy of the Committee's requirement of liners and top and bottom pads was made apparent.

Typical of about fifteen different tests, were the following results: With half-gallon containers, the up-to-date design of carton out-performed the Committee's design by 120 to 60 falls on the conbur test and 142 to 27 falls on the drop test—using 40 percent less paper. . . . With gallon containers with up-to-date design took 42 falls on the conbur as against 14 for the Committee's; on the drums 400 falls as against 38—yet with 28 percent less paper. . . . With peanut butter jars the up-to-date design was 50 percent better with 20 percent less paper. . . . With quart juice bottles, the up-to-date design was twice as good with 20 percent less paper.

Interpreting these tests, Dr. Toulouse said that the studies showed that damage through the outer walls of the shipping container is very remote and that breakdown of inner protection is by far more common. Inasmuch as up-to-date designs out-performed the Committee's designs in every way, an arbitrary design specification is shown

(*Continued on page* 423)

INVENTIONS AND INVENTORS . . .
(Continued from page 402)

assigned to Radio Corporation of America by Harold B. Law.

Fig. 11 is a greatly enlarged section through the finished electrode which is an improvement over what is shown in Patent No. 2,213,179 to Iams. A glass sheet 1 having a thickness between 0.001″ and 0.005″ is first coated with a thin layer of volatile adhesive. Refractory particles having a diameter less than the thickness of the glass are then distributed over the adhesive. Corning 705 glass is recommended, "Best-Test" rubber cement as an adhesive and "Carborundum" of 600 mesh as a refractory.

Fig. 11 — Radio Corporation Electrode for Television.

The glass sheet thus treated is then placed in an oven at about 800°C. where it is allowed to remain for about 5 minutes. This vaporizes the rubber cement and, for some unknown reasons, causes bubbles or depressions to form under each refractory particle. The sheet is then cooled and placed in a hydrofluoric acid solution which dissolves the Carborundum particles and, to some extent, the glass. In one example, the acid treatment is sufficient to open the bubbles to the back of the sheet. This forms a series of very fine perforations which are then filled with metal plugs 9 by the method shown in Patent No. 2,175,701 to Rose.

Patent No. 2,403,225 is a continuation of the above patent and, of course, the same inventor assigned it to RCA. The first patent disclosed an electrode in which the glass sheet was filled with a series of non-uniformly distributed holes which were filledwith metal plugs. The present Patent aims to secure improved results by arranging the holes in a uniform manner.

Fig. 12 — Radio Corporation Electrode for Television.

The finished product shown in a greatly enlarged section in Fig. 12 is made by taking a thin glass sheet as previously described, coating it with "Best-Test" rubber cement and after drying, applying a photographic emulsion. This is then exposed to light through an electrolytic screen which, upon development, produces a series of fine uniformly arranged dots formed by washing away the unexposed emulsion. These minute holes are then filled with silicon carbide and the glass sheet is heated as described in the preceding patent. Various modifications in the method are described to produce the glass sheet 1 leaving perforations 12 as shown in the figure, which are then filled with metal. The original sheet of glass may be made by the method described in an application by Albert Rose on which the patent has not yet issued.

The Patent Office has sent out a notice stating that the printed copies of patents, which now cost ten cents each, will be increased to 25 cents "as soon as the recently passed bill is signed by the President."

When this change goes into effect, it will be necessary to enclose 25 cents in silver, or in Patent Office coupons, with the order for each patent copy. Stamps will not be accepted.

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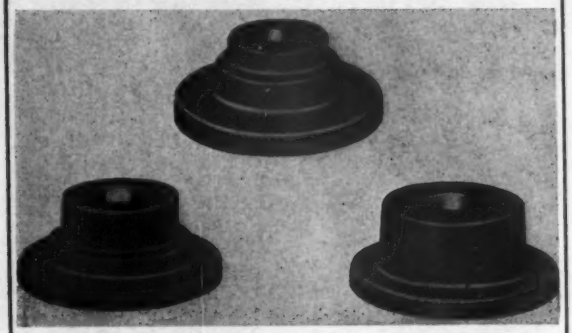

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OBSERVATION OF GOLD PARTICLES IN GLASS . . .

(*Continued from page* 418)

graph, and also as a smaller group in the lower right-hand portion. The crystals are about the same size. In the photograph the cubic crystals measure about 1.8 mm. on a side, which is equivalent to an actual particle size of approximately 115 millimicrons. Figure 4 (d) gives the transmission curve for this glass, which appears blue by transmitted light and a brownish "livery" color by reflected light.

Summary

By various special techniques the particles in gold ruby glass were photographed with the electron microscope. The particles appeared as cubes about 60 millicrons (1/400,000 inch) on an edge in a typical ruby glass. Higher temperature of treatment produced a blue glass with cubic particles about 15 millimicrons on an edge (1/200,000 inch). The size of the particles is in good agreement with other published works dealing with colloidal gold.

FOOTNOTE REFERENCES

1. Taken from article by A. Silverman, "Colloids in Glass", in "Colloid Chemistry", edited by J. Alexander. Vol. III, p. 283 (Chem. Catalog Co., New York, 1931).
2. See R. Zsigmondy and P. A. Thiessen: "Das Kolloide Gold", p. 84. (Akademische Verlag, Leipzig, 1925).
3. G. Mie: Beitrage Zur Optik truber Medien, speziell kolloidaler Metallosungen. Ann. Physik (4), 62, 331 (1920).
4. B. Lange: Uber die Farbung und Entstehung der Gold Rubin und Saphiringlaser. (Veroffentlichungen Aus dem K-W-I fur Silikatforschung in Berlin-Dahlem, 1929).
5. The authors are indebted to Dr. Bernard Long, Laboratoire des Glacerie de la Cie de St. Gobain, for the glass used in these tests.
6. The authors express their appreciation to Professor G. L. Clark, Chemistry Dept., University of Illinois for the use of the electron microscope in his Division.
7. By Prof. J. O. Kraehenbuehl, Dept. of Elec. Eng., University of Illinois.

STANDING COMMITTEES NAMED BY A.G.A.

At a recent meeting of the Board of Governors of the American Glassware Association, Calvin B. Roe, Fostoria Glass Company, was reelected as Chairman of the Board of Governors for the ensuing year.

The following appointments to standing committees were also made: *Tariff Committee:* Chairman, James Gillinder, Gillinder Bros., Inc.; Vice Chairman, C. W. Carlson, United States Glass Company; W. O. Barry, Federal Glass Company; W. L. Orme, Cambridge Glass Company; C. B. Roe, Fostoria Glass Company; C. J. Urhmann, Imperial Glass Company; Louie Wohinc, Louie Glass Company; Guest members, George Dougherty, Secretary of National Association of Manufacturers of Pressed and Blown Glassware; Harry H. Hook, President of American Flint Glass Workers Union; and William G. Muhleman, Vice President of American Flint Glass Workers Union.

Traffic Committee: Chairman, H. S. McCafferty, Federal Glass Company; I. L. Dunnington, Anchor Hocking Glass Corporation; A. W. Koenemund, Fostoria Glass Company; John Metz, Corning Glass Works; C. T. Meyerhoff, Owens-Illinois Glass Company, Libbey Division; J. L. Sprowls, Hazel-Atlas Glass Company; and J. H. Stevenson, Jeannette Glass Company.

The firm of Stevenson, Jordan & Harrison, Inc., was again selected and employed as Managing Director of the Association.

PROPOSED SHIPPING CARTON RULES . . .

(*Continued from page* 420)

to be untenable. Future designs might well be found which are still better, but this is a matter of time for research and trial. Meanwhile, adoption of a specification provision in Rule 41 would stifle such research and leave no incentive for progress.

In a concluding statement Mr. Taylor pointed out to the Committee that the rise in the claim account in 1942 was coincidental with ODT General Order 18, calling for loading cars to maximum carrying capacity. He referred to authoritative statements that railroads saved thereby the cost of millions of carload shipments. He stated that the railroads had been the chief beneficiaries of this order. And he tendered the belief that carriers would not exchange the benefits they had received for a much larger claim account than they have had.

Mr. Taylor also pointed out to the Committee that in the explanatory statement in the first issue of General Order 18 there is an implied invitation to shippers to seek rate adjustments if heavier loading of cars justifies such action, but that so far as he knew no such adjustment had been sought.

No formal decision on these hearings is necessary. The railroads may forego further action or, although unlikely, declare the proposed specifications in effect. If the latter course is pursued, shippers may then petition the Interstate Commerce Commission to adjudicate the case.

• C. J. Richter, who is well-known to the glass industry, has been appointed Chief Engineer of Tate-Jones & Co., Inc., and Tate-Jones International Export Corporation.

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